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Soil Survey of Iowa, Report No. 38—Hardin County

W. H. Stevenson
Iowa State College

P. E. Brown
Iowa State College

SOIL SURVEY OF IOWA

HARDIN COUNTY

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

Agronomy Section
Soils

Soil Survey Report No. 38
August, 1925
Ames, Iowa

IOWA AGRICULTURAL EXPERIMENT STATION

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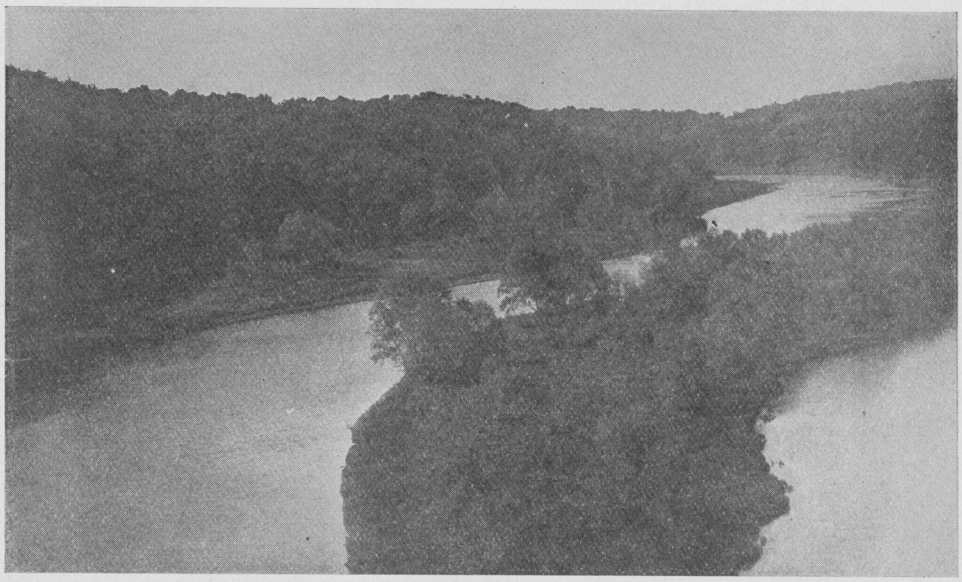
August, 1925 Soil Survey Report No. 38

SOIL SURVEY OF IOWA

Report No. 38--HARDIN COUNTY SOILS

By W. H. Stevenson and P. E. Brown, with the assistance of T. H. Benton, L. W. Forman and J. L. Boatman



The Iowa river flows thru a narrow gorge-like valley from Eagle City to Secor.

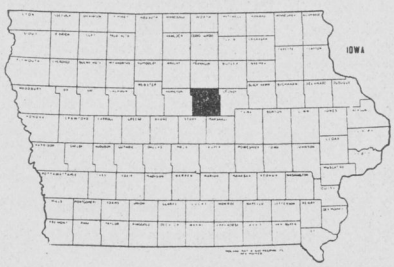
IOWA AGRICULTURAL
EXPERIMENT STATION
C. F. Curtiss, Director
Ames, Iowa

CONTENTS

HARDIN COUNTY SOILS*

By W. H. Stevenson and P. E. Brown with the assistance of T. H. Benton, L. W. Forman and J. L. Boatman

HARDIN county is located in central Iowa in the fourth tier of counties south of the Minnesota state line and in the sixth tier west of the Mississippi River. It lies partly in the Wisconsin drift soil area and partly in the Iowan drift and Southern Iowa loess areas. The soils of the county are therefore of glacial and loessial origin, the major portion of the area being covered by glacial soils.



The total area of the county is 569 square miles or 364,160 acres. Of this area, 343,758 acres, or 94.3 percent, is in farm land. The total number of farms is 2,083 and the average size of the farms is 165 acres. The following figures from the Iowa Yearbook of Agriculture for 1923 show the utilization of the farm land in the county.

Acreage in general farm crops	240,651
Acreage in farm buildings, feed lots and public highways	18,472
Acreage in pasture	81,464
Acreage in waste land	1,065

The present type of agriculture followed in Hardin county consists of general farming, including the growing of grain and the raising of stock. The sale of livestock provides the chief source of income on most farms but in some parts of the county considerable amounts of grain are sold. Hog raising and feeding is the most important livestock industry with the raising and feeding of cattle of secondary importance. Some dairying is practiced, but it is chiefly a side line.

Corn is the chief crop grown. It is estimated that about three-fourths of the crop is fed on farms and the remainder is sold out of the county. Oats are grown on practically all farms and somewhat more than half of the crop produced is used for feed. On many farms, particularly tenant farms, oats serve as a cash crop. In the northwest corner of the county more of the grain produced is marketed and there is less feeding. In some other parts of the county feeding seems to be practiced more extensively, but in general it may be said that there is less feeding on tenant farms, more of the corn and oats being sold, while on farms operated by the owners practically all of the crops produced are used for feed.

The area in waste land in the county is quite large and such land may be reclaimed and made productive thru the adoption of proper methods of soil treatment. It is impossible to make general recommendations regarding the handling

*See Soil Survey of Hardin County, Iowa, by T. H. Benton of the Iowa Agricultural Experiment Station and W. W. Strike of the U. S. Department of Agriculture.

TABLE I. AVERAGE YIELDS AND VALUE OF CROPS GROWN IN HARDIN COUNTY, IOWA*

Crop	Acres	Percent of total farm land of county	Bushels or tons per acre	Total bushels or tons	Average price	Total value of crops
Corn	127,080	36.96	38.0	4,829,040	$0.62	$2,994,004
Oats	80,783	23.49	39.0	3,150,537	0.37	1,165,708
Winter wheat	230	0.06	20.0	4,600	0.89	4,094
Spring wheat	47	0.01	18.0	846	0.87	736
Barley	1,051	0.30	33.0	34,683	0.52	18,035
Rye	50	0.01	28.0	1,400	0.66	924
Potatoes	695	0.20	73.0	50,735	0.77	39,065
Tame hay	26,648	7.75	1.4	37,307	12.50	466,337
Wild hay	3,471	1.00	1.0	3,471	10.50	36,445
Alfalfa	596	0.17	3.1	1,848	16.25	30,030
Pasture	81,464	23.69	....	.....	.....	.....

*Iowa Yearbook of Agriculture 1923.

of waste land as the causes for the infertility of the land are quite variable. In a later part of this report treatments which are desirable under special soil conditions will be suggested. Advice regarding the treatment of soils in special cases for more or less abnormal conditions may be secured from the Soils Section of the Iowa Agricultural Experiment Station upon request.

The general farm crops grown in Hardin county in the order of their importance are: corn, oats, hay, potatoes, alfalfa, barley, wheat and rye.

The average yield and value of these crops in the county are given in table I. Corn is by far the most important crop in the county both in acreage and in value. It is grown on 36.96 percent of the total farm land of the county. Average yields in 1923 were reported at 38 bushels per acre. In favorable seasons yields as high as 80 bushels per acre are frequently secured on the better soils of the county. The popular varieties grown are Reid's Yellow Dent, Silver King, Calico and Western Plowman. The yellow corn seems to be most generally preferred except in Aetna township. Probably about half of the seed used is pure and the remainder of mixed strains. A large part of the corn grown is used for silage, the amount put up in 1923 amounting to 37,670 tons. The number of silos in the county is 379. Growing soybeans in the corn for silage is becoming popular. About 70 percent of the corn crop is fed on the farms. A small part of the remainder is sold locally but the major portion is disposed of on the markets in Chicago, St. Louis and Omaha. There are 17 cooperative elevators in the county and most of the grain shipped is handled thru these elevators.

The oats crop is second in importance in the county, the crop being grown on practically every farm. It occupies 23.49 percent of the total farm land of the county. Average yields in 1923 amounted to 39 bushels per acre. The chief varieties grown are Iowa 105, Iowa 103, Silver Mine and Green Russian, the two latter being late varieties. About 60 percent of the oats grown is of early varieties. More than 50 percent of the entire oat crop is used for feed on the farms. On many tenant farms it serves as a cash crop, while on many of the farms operated by the owners very little of the crop is sold.

The third crop in importance in the county is hay. Tame hay is grown on 7.75 percent of the farm land in the county, and average yields in 1923 amounted to 1.4 tons per acre. Timothy and clover mixed is the main hay crop. Very little timothy is grown alone. Some clover is grown alone both for seed and for hay. Average yields of this crop amount to 1½ to 2 tons per acre. There is some wild hay cut in the county in the low poorly drained draws and depressions. Practically all of the hay crop in the county is fed on the farms and in fact some hay is shipped in, in some parts of the county, for feeding.

Potatoes are grown on practically all farms but chiefly to supply the home demand. Some surplus is produced in the eastern part of the county. Average yields of this crop amount to 73 bushels per acre. In general, there is not a sufficient production of potatoes to supply the needs of the county.

Alfalfa is grown on a comparatively small acreage in the county but the value of the crop is considerable. Average yields of this crop amount to 3.1 tons per acre. Usually three cuttings are made and in many cases the yields will amount to 4 tons. When the land is well drained and well supplied with lime and the alfalfa is inoculated very satisfactory yields may be secured. Difficulties in securing a good crop are usually traceable to some one of the factors mentioned or to poor seed or poor seasonal conditions. As more is learned about growing this crop it will undoubtedly be raised more extensively because of its value.

Barley is grown on a small acreage in the county and average yields of 33 bushels per acre are reported. It is sometimes substituted for oats in the rotation. All of the barley produced is fed on the farms.

Wheat is grown only to a small extent in the county and is of little importance. In 1923 there were only 47 acres of spring wheat and 230 acres of winter wheat. Average yields of the former amount to 18 bushels per acre while the winter varieties yield 20 bushels.

Other crops of minor importance in the county include buckwheat, kaffir, rye and emmer. Some sorghum is grown for syrup. Sudan grass is produced in some areas and a little millet is grown. Sweet clover sometimes is grown for hay and pasture and very good results are reported. Soybeans are grown mainly for silage, being planted with the corn. The Mongol and Medium Green varieties are the most commonly used. Some soybeans are utilized in the corn for hogging down. In these cases the Manchu and Ito San varieties are grown. Rape is sometimes seeded in the corn with the last cultivation and serves for feed.

Some sweet corn is grown, chiefly in the northeast corner in Aetna township. Average yields are 6 or 7 tons per acre. The crop is disposed of largely at the canning factory in Ackley. Considerable popcorn is grown in the vicinity of Hubbard. Trucking is practiced in a small way around Eldora and Iowa Falls on the sandier uplands and terrace soils. Sweet potatoes, melons and other truck crops are grown on these areas.

Fruit growing is not practiced extensively but there are orchards on most farms and some small fruits are grown for home consumption. Apples are the chief tree fruit, the most common varieties being Northwestern Greening, Jonathan, Baldwin, Oldenburg, Wealthy, Malinda and Pewaukee. Some cherries, plums and pears are grown. Grapes, raspberries, strawberries, gooseberries, blackberries and currants do well thruout the county. The silty soils in the

southern and eastern parts of the county seem to be the best adapted to fruit growing and more fruit is actually produced in these areas.

The livestock industries of the county include hog raising and feeding, cattle raising and feeding, dairying, sheep raising and feeding and the raising of horses and mules. The following figures taken from the Iowa Yearbook of Agriculture for 1923 show the extent of the livestock industry in the county.

Horses, all ages	11,635
Mules, all ages	764
Swine, on farms July 1, 1923	133,728
Swine, on farms Jan. 1, 1924	96,654
Cattle, cows and heifers kept for milk	13,523
Cattle, other cattle not kept for milk	33,949
Cattle, total all ages, Jan. 1, 1924	47,472
Sheep, all ages on farms Jan. 1, 1924	3,431
Sheep, shipped in for feeding, 1923	7,711
Sheep, total pounds of wool clipped	22,364
Poultry, total all varieties, Jan. 1, 1924	352,638
Poultry, number dozen eggs received 1923	1,462,635

The raising and feeding of hogs is the most important livestock industry and the number on the farms January 1, 1924 was 96,654. The average number of hogs per farm is 65. Most of the hogs are mixed grades but there are many purebred herds. Duroc Jersey, Poland China, Hampshire, Chester White and Spotted Poland Chinas are the leading breeds. Some hogs are shipped in for feeding. Marketing is carried on largely thru the Cooperative Livestock Shipping Association, most of the hogs going to Chicago with a few to Mason City and Cedar Rapids. The sale of hogs provides the main income on most farms.

Cattle raising and feeding is second in importance and much income on the farms is derived from this industry. Most of the cattle are grades. About 5 percent of the cattle are purebred, the favorite breeds being, Shorthorn, Angus Holstein and some Hereford, Jersey and Red Poll. About 300 cars of feeders are shipped into the county annually. They are sold mainly on the Chicago market.

Dairying is not practiced on a large scale but is an important sideline industry on most farms. There are several strictly dairy farms near Eldora and Iowa Falls. The most popular breed of dairy cattle is the Holstein. On most farms the cows are grade Shorthorns or Holsteins. There are four cooperative and three commercial dairies in the county and cream buying stations in nearly every town. The average farmer keeps 8 to 10 cows and sells some of the milk to the local cream buying stations. The creamery at Iowa Falls makes a considerable amount of butter which is shipped to New York City.

Some sheep are raised on the rougher land along the Iowa River. The flocks are usually small. The Oxford and Shropshire are the most popular breeds. Several car loads of sheep are shipped in each year for feeding and they are sold largely on the Chicago market. The wool clipped is practically all marketed thru the Iowa Wool Growers Association and sold in Chicago.

A few horses are raised on farms, the Percheron being the favorite breed. Some mules are also raised. There is hardly enough raising of horses and mules, however, to keep up the supply of work stock.

Poultry are raised on all farms, the flocks consisting mainly of chickens with a few geese, ducks, turkeys and guinea fowls. They average 175 and are largely of mixed breeds. The egg production in 1923 amounted to over one and a third million dozen eggs. The poultry and poultry products are disposed of largely on the Boston market with considerable sale on the local markets.

The value of land in Hardin county is somewhat variable depending upon the location with reference to towns and to railroad facilities, to improvements on the farms and general soil conditions. The average price of farm land is around $250 per acre. Selling prices range from $175 to $400 per acre. It is generally recognized that the land in the county is very valuable for farming purposes, and it is priced accordingly.

The yields of general farm crops secured in Hardin county are usually quite satisfactory, but by proper methods of soil treatment larger crops may often be secured. The actual treatments needed will vary with the different soils and the particular conditions but there are certain general recommendations which can be made for the improvement of crop growth on many of the soils of the county.

The drainage conditions are not entirely adequate in some areas and drainage is sometimes the first treatment needed to make the soils satisfactorily productive. If the land is too wet, crop yields will be low and other soil treatments will be valueless. The first thing needed on such areas is the proper installation of tile. The benefit from tiling out wet land is always large.

Many of the soils in the county are acid in reaction and in need of lime if the best growth of general farm crops and particularly of legumes is to be secured. Some of the types, such as those of the Webster series, are well supplied with lime and in such cases additions are unnecessary. The only way to determine the need for lime is by having the soils tested. The amount of lime needed to neutralize the acidity present may then be applied. It is quite important for the best growth of leguminous crops in the county that all of the soil be tested regularly, and the lime requirement or acidity determined.

Most of the soils in the county are generally well supplied with organic matter but some of the types are rather deficient in this material. Applications of farm manure are very desirable on all of the soils of the county. Even on those which are apparently better supplied with organic matter it is very important that the supply be maintained. On the poorer types, liberal additions of farm manure are particularly necessary. Large increases in crop growth are secured both on these poorer types and also on the better soils, from the use of manure. In many cases it is important that leguminous crops be used as green manures. The practice of green manuring is especially necessary on the light colored, sandy soils but it is a practice which may also be followed to advantage on many other types on which farm manure can not be applied. It serves usually as a supplement to or substitute for farm manure.

The nitrogen content of the soils of the county is not low in most cases but it must be maintained. This may be done by the proper use of well inoculated legumes as green manures, as well as by the thoro utilization of all farm manure.

The phosphorus supply in the soils of the county is rather low and it is apparent that phosphorus fertilizers will be needed on these soils in the near

future, in fact it seems quite probable that desirable results would be secured from the use of these materials at the present time. It is recommended that tests of phosphate fertilizers be carried out on small areas to determine the need of phosphorus. Acid phosphate and rock phosphate may both be used in such tests and their relative value determined under the particular conditions.

Complete commercial fertilizers may also be tested on small areas if desired but the results secured with these materials should always be compared with the effects of acid phosphate, as the latter material is likely to prove more profitable. Complete fertilizers cannot be recommended for use in the county at the present time, but there are indications from the greenhouse and field tests given later in this report that phosphate fertilizers may often be used with profitable effects. Whether acid phosphate or rock phosphate is the most profitable has not yet been determined.

Erosion occurs to some extent in the county and it is very desirable that some methods be adopted to prevent the extensive washing away of surface soil and the formation and development of gullies. Where the latter occur it is important to employ some means of filling the gully and reclaiming the area. Suggestions are offered later in this report for the control and prevention of erosion, and from among these, some method may be chosen which will be suitable for the particular condition.

THE GEOLOGY OF HARDIN COUNTY

The rock materials underlying the soils of Hardin county are deeply buried by the glacial and loessial deposits of later ages and none of the soils in the county are derived from the native bed rock. Only in very few instances does the rock material occur sufficiently close to the surface to have any effect whatever upon the soil conditions. The soils have all been formed from the glacial and loessial deposits and practically everywhere these deposits extend to great depths before the bed rock is reached.

During the glacial age at least three great glaciers swept over the county entirely or in large part, and upon their retreat they left behind a vast mass of debris or glacial till. The earlier glacial deposits were carried away to a large extent by the later glaciers. The earlier topographic features of the county established following each glaciation were largely obliterated. Each glacier left a thick mass of till or drift material but the earlier drift deposits have little effect upon the present surface soil conditions. The geological history of the county is of interest only in so far as it concerns the glacial age.

The earliest glacier, known as the Kansan, left behind a deposit consisting mainly of boulder clay which varies in color from a bright yellow to a deep reddish-brown where it has been oxidized and to a blue color in the deeper unoxidized portions. Boulders are of frequent occurrence and pockets of sand and gravel commonly occur. The depth of the Kansan deposit varies from a few feet to nearly 100 feet in thickness in some places. The deposit left by the Kansan glacier affects the soils of the county only in the eastern part where the deposit has been covered in more recent years by a thin covering of loess. In the

SOIL MAP OF HARDIN COUNTY, IOWA

Thomas D. Rice, Inspector Northern Division.
Soils surveyed by T. H. Benton, of the Iowa Agriculture Experiment Station in charge and W. W. Strike of the U. S. Department of Agriculture.

U. S. DEPT. OF AGRICULTURE, BUREAU OF SOILS
Milton Whitney, Chief. Curtiss F. Marbut, in charge Soil Survey.

IOWA AGRICULTURAL EXPERIMENT STATION
C. F. Curtiss, Director. W. H. Stevenson, in charge Soil Survey.
P. E. Brown, Associate in charge.

LEGEGND

Drift Soils

1 Carrington loam	57 Carrington loam (steep phase)	138 Clarion loam
107 Webster silty clay loam	55 Webster loam	83 Carrington silt loam
65 Lindley loam	187 Lindley loam (steep phase)	137 Lindley very fine sandy loam
85 Clyde silty clay loam	4 Carrington fine sandy loam	3 Carrington sandy loam

Loess Soils

120 Tama silt loam	80 Clinton silt loam	163 Fayette silt loam
	30 Muscatine silt loam	

Terrace Soils

108 O'Neill loam	38 Buckner loam	75 Waukesha silt loam
188 Millsdale loam	109 Fargo silty clay loam	45 Buckner fine sandy loam
	43 Bremer silty clay loam	

Swamp and Bottomland Soils

49 Wabash loam	111 Lamoure silty clay loam	26 Wabash silt loam
48 Wabash silty clay loam		21 Peat and Muck

Scale: 1 Inch 2½ Miles

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case of the Lindley soils, the Kansan drift makes up a large part of the soil section of the various types mapped in the series.

Somewhat later a second glacier invaded the county burying the Kansan deposit to a very large extent and covering the county with a layer of till which is now known as the Iowan drift. It usually extends to depths of not more than 10 feet and is light to bright yellow in color and somewhat sandier than the Kansan material. Boulders are of frequent occurrence. It gives evidence of its more recent origin because of the less extensive leaching and oxidation than is the case in the Kansan material. This glacial deposit, like the Kansan, is of interest only in the extreme eastern part of the county. The soils of the Clyde series seem to be derived from the Iowan drift and it affects to a large extent the character of some of the loess soils as it occurs within the three foot section, being covered by a thin layer of loessial material. Thus it may affect the characteristics of the Lindley series. The deposit may also occur underlying the various other loessial types.

About four-fifths of the county, including the entire western portion, was covered at a still later date by a glacial deposit known as the Wisconsin. This deposit is variable in depth, as it filled the earlier valleys and covered the knolls, leveling the previous topographic features to a very large extent and covering the earlier deposits. It may range from 6 to 15 feet in depth extending even deeper in some areas. The lower layers of the Wisconsin drift material are composed of a blue boulder clay containing boulders and gravel. The upper part of the deposit is a dull yellow in color and gives evidence of having undergone little weathering, leaching or oxidation. The lower layers are usually high in lime and will effervesce with acid. Frequently the lime is high also in the surface soil. Many portions of the area covered by the deposit are poorly drained and the soils give evidence of their more recent formation and show large accumulations of organic matter. The soils of the Carrington, Clarion, Webster and Clyde series on the upland are derived from the Wisconsin drift. Variations occurring among these series are the result of differing topographic conditions and drainage and varying accumulations of organic matter from vegetation growth and decay. Differences in color and lime content are brought about entirely by the variations in weathering and drainage. Many of the terrace and bottomland soils are derived in large part from the Wisconsin drift material, and in fact, thruout the western four-fifths of the county where the Wisconsin drift soils occupy the upland, the terrace and bottomland soils may be considered to be almost entirely of drift origin.

At a later time following the glacial age there was deposited over the eastern and southeastern parts of the county a covering of wind blown material known as loess. This deposit was made at a time when climatic conditions were very different than at present, but presumably the loess is of wind formation. The deposit was laid down uniformly over the existing topographic features. The deposit largely covers the early Kansan and Iowan drift in the eastern part of the county east of the Iowa river and the southeastern corner in a large part of Providence and Union townships. The loessial deposit was not thick but was probably originally quite uniform in depth. At the present time however, there has been so much washing away of the loessial covering in many areas that the deposit now ranges from only a few inches to 6 or 7 feet in depth.

In an unweathered condition loess is an even grained material composed mainly of silt. It ranges in color from a light grayish-brown to yellowish-brown. Organic matter has accumulated in varying amounts. The soils mapped in the Tama, Lindley, Clinton, Fayette and Muscatine series are of loessial origin. The Tama soils have been developed in the well drained rolling areas of prairie. The Muscatine soils have formed in the rather poorly drained prairie areas. The Clinton and Fayette soils have been formed in the more rolling to rough forested areas and they are distinctly lighter in color and less naturally productive. The Lindley soils have also been formed under forested conditions but they are characterized by the thin covering of loess which remains. The terrace and bottomland soils in the eastern part of the county are derived partly from the loess on the uplands, but there is always a considerable mixture of drift material so that the terrace and bottomland soils in the county generally may be considered largely of drift origin.

PHYSIOGRAPHY AND DRAINAGE

The topographic features of Hardin county seem to have a rather direct relation to the early geological or glacial history. Thus the western portion of the area covered by the Wisconsin drift deposit shows a rather flat topography with the occurrence of saucer-like depressions, low winding ridges and occasionally knob-like hills. The principal streams cut thru these areas with rather deep channels but they have only a few tributaries and these are usually quite inextensive. The drainage of the land in this portion of the county is frequently quite inadequate and especially thruout those areas where the Webster soils predominate the drainage is poor.

To the east of this Wisconsin drift plain there is a chain of hills and ridges rising 6 to 30 feet which is known as the Altamont Moraine and varies in width from two to five miles entering the county in Aetna township and extending southward past Eldora and then southwest into Marshall county. East of this morainic area the topography is gently rolling to strongly rolling. The typical Iowan drift topography occurs in the northeastern part of the county. In both cases the soil is of loessial origin but the earlier drift topography is apparent.

The whole region east of the moraine is better drained than the western part of the county. The topographic features bear evidence of that better drainage. Terraces and bottomlands are developed along the main streams of the county, usually, in narrow strips, however. Frequently the streams are bordered by the upland and there is practically no bottomland. This is true along some parts of the Iowa River.

The drainage of the county is brought about mainly by the Iowa river and its tributaries. It is estimated that this river carries more than 90 percent of the drainage water of the county. A small area in the northeastern corner is drained by tributaries of the Cedar River. In the extreme southwestern corner Indian Creek, a tributary of Skunk river, carries the drainage. The chief tributaries of the Iowa river are, Beaver Creek, South Fork Iowa river, Tipton Creek, and Honey, Minerva, Mud, Bear, Cedar and Pine Creeks. The three latter are tributaries to the east of the river.

The Iowa river has cut thru the drift and the valley of the river varies in depth from 70 to 175 feet. The channel ranges from 100 to 400 feet in width. Along parts of the course of the river there is wide variation in the character of the valleys. Between Gifford and Alden the river flows thru a rather close walled gorge, 150 to 175 feet in depth. At Iowa Falls, the river has cut thru solid limestone which rises 30 to 70 feet above the river bed. In other parts of the course of the river the flood plain is wider and in general it averages three-eighths of a mile in width. The South Fork of the Iowa river is the most important tributary. In the northwestern part of the county it has all of the characteristics of a prairie stream. Toward the southeast, however, the channel becomes wider and deeper and in some places it has cut thru ridges to a depth of 50 to 125 feet. Very little bottomland occurs along this stream until the lower course is reached, where it joins the Iowa river. Most of the remaining streams in the county are mainly sluggish prairie streams. Beaver Tipton and Honey creeks flow thru deeper channels along parts of the courses while Mud, Indian and Minerva are typical prairie streams. The creeks join-

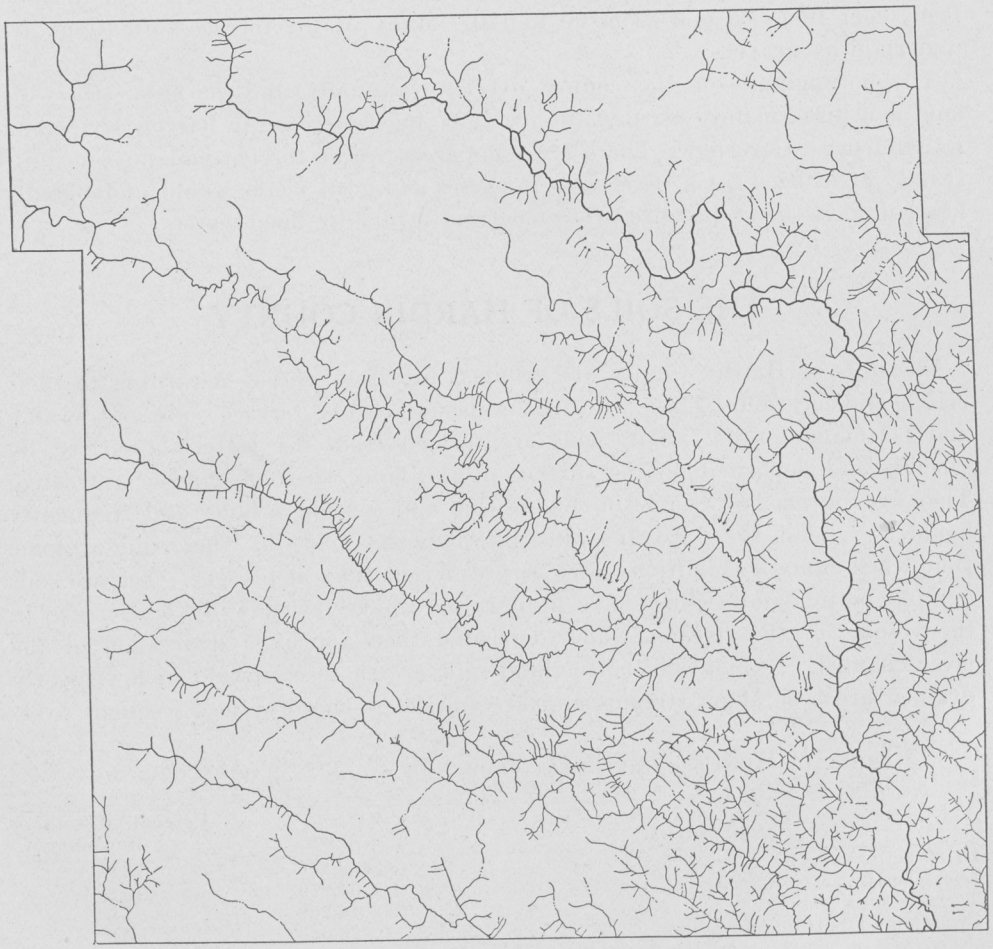

Fig. 1. Map of natural drainage system of Hardin county.

ing the Iowa river flow thru deeper channels showing some terrace formations and narrow areas of bottomland.

Most of the large streams in the western part of the county are rather poorly supplied with tributaries and the drainage of the county, as indicated on the accompanying map, is rather poor.

The installation of tile is frequently necessary in order to bring considerable areas of the upland into the highest state of productivity. Considerable drainage has been carried out in the county and much tile has been installed together with some open ditches, but there are some areas which are still in need of more thoro removal of excessive moisture. East of the morainic area the drainage is better and it is only infrequently that tiling is needed.

The bottomlands of the county are about 100 feet wide near the edges of the streams, gradually widening out along the lower courses. They are generally level except in areas which are being continually reworked by the streams. Terraces or second bottoms occur mainly along the Iowa river, South Fork of the Iowa river and Beaver creek. A few small areas occur along some of the small creeks. They occur at different elevations above the streams, from 10 to 30 feet, from 40 to 65 and from 90 to 110. Many of the terrace formations are underlaid by gravel.

The bottomlands of the county overflow annually and in most cases the land is utilized mainly for pasture, owing to its occurrence in narrow strips and its tendency to overflow. There are some areas where the bottomland can quite readily be utilized for general crop purposes and good yields would undoubtedly be secured if the crops were protected from injury by flood waters.

THE SOILS OF HARDIN COUNTY

The soils of Hardin county are grouped into four classes according to their origin and location. These are drift soils, loess soils, terrace soils and swamp and bottomland soils. Drift soils are formed from the materials carried by glaciers and deposited on the surface of the land when the glacier retreated. They are extremely variable in composition and contain pebbles and frequently boulders. Loess soils are fine, dust-like deposits made by the wind at some time when climatic conditions were very different than at present. Terrace soils are old bottomlands which have been raised above overflow by a decrease in the volume of the streams which deposited them, or by a depression of the river channel. Swamp and bottomland soils are those occurring in low, poorly drained areas or along streams and are subject to more or less frequent over-

TABLE II. AREAS OF DIFFERENT GROUPS OF SOILS IN HARDIN COUNTY.

Soil group	Acres	Percent of total area of county
Drift soils	269,376	73.9
Loess soils	54,976	15.2
Terrace soils	16,768	4.6
Swamp and bottomland soils	23,040	6.3
Total	364,160	....

TABLE III. AREAS OF DIFFERENT SOIL TYPES IN HARDIN COUNTY.

Soil No.	Soil Type	Acres	Percent of total area of county
	DRIFT SOILS		
1	Carrington loam	125,632	35.2
57	Carrington loam (steep phase)	2,624	
138	Clarion loam	70,912	19.5
107	Webster silty clay loam	36,608	10.0
55	Webster loam	11,392	3.1
83	Carrington silt loam	5,120	1.4
65	Lindley loam	2,880	1.3
187	Lindley loam (steep phase)	1,984	
137	Lindley very fine sandy loam	3,968	1.1
85	Clyde silty clay loam	3,264	0.9
4	Carrington fine sandy loam	3,136	0.9
3	Carrington sandy loam	1,856	0.5
	LOESS SOILS		
120	Tama silt loam	47,872	13.2
80	Clinton silt loam	4,224	1.2
163	Fayette silt loam	1,536	0.4
30	Muscatine silt loam	1,344	0.4
	TERRACE SOILS		
108	O'Neill loam	7,872	2.2
38	Buckner loam	2,304	0.6
75	Waukesha silt loam	2,240	0.6
188	Millsdale loam	1,856	0.5
109	Fargo silty clay loam	960	0.3
45	Buckner fine sandy loam	832	0.2
43	Bremer silty clay loam	704	0.2
	SWAMP AND BOTTOMLAND SOILS		
49	Wabash loam	11,904	3.3
111	Lamoure silty clay loam	5,184	1.4
26	Wabash silt loam	3,008	0.8
48	Wabash silty clay loam	1,472	0.4
21	Peat and Muck	1,472	0.4
	Total	364,160	....

flow. The extent and occurrence of these four groups of soils in Hardin county are shown in table II.

Almost three-fourths of the county, 73.9 percent, is covered by the drift soils, the entire western and central portions of the county having mainly glacial upland soils. The loess soils cover 15.2 percent of the total area of the county. They occur in the eastern part of the county, being most extensive in the southeastern townships. The terrace soils are small in area covering 4.6 percent of the total area of the county. The bottomland soils are slightly larger covering 6.3 percent of the total area of the county. They are found along practically all of the rivers and creeks of the county and mainly in narrow areas.

There are 25 individual soil types in the county and these with the steep phase of the Carrington loam, the steep phase of the Lindley loam and the areas of peat and muck make a total of 28 soil areas. There are 12 areas of drift soils, 4 loess types, 7 terrace soils and 5 areas of swamp and bottomland. The various soil types are distinguished on the basis of certain definite characteristics which are described in the appendix to this report and the names indicate certain group characteristics. The areas covered by the various soil types in the county are given in table III.

The Carrington loam is the largest individual soil type. With the steep phase, which is very small in area, it covers 35.2 percent of the total area of the county. The Clarion loam is the second largest type, covering 19.5 percent of the county. The Tama silt loam is the largest loess type and the third most extensive soil in the county, covering 13.2 percent of the county. The Webster silty clay loam is the third drift soil in extent and fourth in the county, covering 10.0 percent of the total area. The Webster loam is much smaller in area, covering only 3.1 percent of the county. The Wabash loam is the largest bottomland type, covering 3.3 percent of the county. The O'Neill loam is the largest terrace soil, but it covers only 2.2 percent of the county. The remainder of the terrace types are all small in area, covering less than one percent of the county. The Carrington silt loam, Lindley loam with the steep phase and the Lindley very fine sandy loam cover 1.4, 1.3, 1.1 percent of the county, respectively. The remainder of the drift soils cover less than one percent of the total area. The Clinton silt loam covers 1.2 percent of the county. The remaining two loess soils comprise less than one percent of the total. The Lamoure silty clay loam is the second largest bottomland soil. It covers 1.4 percent of the county. The remainder of the bottomland types are small in extent, constituting less than one percent of the total area.

The upland soils of the county vary considerably in topography, ranging from those areas which are mapped as steep phases of the Carrington loam and the Lindley loam to areas of the Webster soils which are level to flat in topography, and to the depressed areas of the Clyde silty clay loam. The loessial uplands vary from the more steeply rolling Clinton and Fayette soils thru the more gently rolling Tama types to the level Muscatine soils. The predominant topography of the upland, however, both in the drift and loess areas, is gently rolling to rolling. This is the typical topography of the more extensive soils of the Carrington, Clarion and Tama series. The terraces and bottoms are more or less level in topography and the latter soils are subject to overflow.

THE FERTILITY OF HARDIN COUNTY SOILS

Samples were taken for analysis from each of the soil areas in the county except the steep phase of the Carrington loam, the steep phase of the Lindley loam, and the area of peat and muck. These soils were not sampled because of their small areas and the fact that they are of little importance agriculturally. The area of peat and muck was not sampled owing to its variability in character and to the fact that many analyses of peat have been made and the composition varies but little.

The more extensive soil types were sampled in triplicate while only one sample was taken from each of the minor types. Samplings were all made with the utmost care that the samples be representative of the particular soil types and that variability due to various treatment should be eliminated. The samples were taken at three depths, 0 to 6 2/3 inches, 6 2/3 to 20 inches and 20 to 40 inches, representing the surface soil, the subsurface soil and the subsoil, respectively.

The samples were all analyzed for total phosphorus, total nitrogen, total organic carbon, total inorganic carbon and limestone requirement. The official

methods were followed in the determination of the phosphorus, nitrogen and carbon and the Truog qualitative test was used in the determination of the limestone requirement. The figures given in the tables are the averages of the results of duplicate determinations on all samples of each type and they represent, therefore, the averages of 4 or 12 determinations.

THE SURFACE SOILS

The results of the analyses of the surface soils are given in table IV. They are calculated on the basis of two million pounds of surface soil per acre.

The phosphorus content in the various soil types is somewhat variable, ranging from 633 pounds per acre in the Carrington fine sandy loam up to 1,736 pounds in the Lamoure silty clay loam. No very definite relations are apparent between the phosphorus content of the soils in the different groups, wide variations occurring among the types within each group. The average of the bottomland soils is somewhat higher than the average of the other groups, as might be expected inasmuch as there has been less crop growth on these types and a smaller removal of plant food constituents. The relationships among the individual soil types are much more definitely indicated.

TABLE IV. PLANT FOOD IN HARDIN COUNTY, IOWA SOILS

Pounds per acre of two million pounds of surface soil (0—6⅔")

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
	DRIFT SOILS					
1	Carrington loam	969	3,293	35,562	0	8,000
138	Clarion loam	1,158	4,920	49,545	7,839	0
107	Webster silty clay loam	1,465	6,340	64,127	0	2,000
55	Webster loam	1,320	4,720	54,545	0	2,000
83	Carrington silt loam	1,347	4,760	59,514	0	6,000
65	Lindley loam	1,050	1,880	21,130	0	3,000
137	Lindley very fine sandy loam	1,091	3,440	36,527	0	5,000
85	Clyde silty clay loam	1,508	12,120	130,057	0	2,000
4	Carrington fine sandy loam	633	1,080	16,926	0	3,000
3	Carrington sandy loam	915	1,600	26,863	0	7,000
	LOESS SOILS					
120	Tama silt loam	1,205	4,540	50,778	0	8,000
80	Clinton silt loam	1,023	2,400	25,498	0	3,000
163	Fayette silt loam	1,225	4,120	49,686	0	8,000
30	Muscatine silt loam	1,481	5,520	60,659	0	8,000
	TERRACE SOILS					
108	O'Neill loam	821	3,360	33,251	0	8,000
38	Buckner loam	1,131	3,240	33,524	0	5,000
75	Waukesha silt loam	1,185	4,360	51,378	0	8,000
188	Millsdale loam	1,575	2,400	63,172	0	6,000
109	Fargo silty clay loam	1,320	5,480	77,968	0	3,000
45	Buckner fine sandy loam	821	1,600	23,751	0	6,000
43	Bremer silty clay loam	1,144	5,840	66,939	0	6,000
	SWAMP AND BOTTOMLAND SOILS					
49	Wabash loam	1,414	3,000	48,703	0	8,000
111	Lamoure silty clay loam	1,736	8,360	87,622	14,534	0
26	Wabash silt loam	1,293	4,960	60,114	0	2,000
48	Wabash silty clay loam	1,615	5,440	71,908	0	2,000

Some relations are evident between the different series. Thus, among the drift types the Webster soils are higher in phosphorus than the Carrington, Clarion and Lindley soils. The Clyde is somewhat better supplied than the Webster types. The Clarion is richer than the Carrington. Among the loess types the Muscatine soils are higher than the other types. The Tama and Fayette are somewhat better supplied than the Clinton. On the terraces the Fargo and Millsdale soils are the best supplied with phosphorus, the Bremer and Waukesha coming next, with the O'Neill and Buckner the lowest. On the bottoms the Lamoure soils are slightly richer in this constituent than the Wabash types. Undoubtedly these variations in phosphorus content are a reflection of certain characteristics which serve to distinguish the different series. Probably the relation is traceable to several characteristics and among these may be mentioned, topography, color, and subsoil characteristics. Thus the Webster and Clyde soils are blacker in color, more level in topography and have heavier subsoils than the other drift series which show smaller amounts of phosphorus. The Muscatine series is darker in color, more level in topography and has a heavier subsoil than the Tama, Clinton or Fayette series which contain less phosphorus. Similarly, on the terraces the Fargo and Bremer soils, from their color, topography and subsoil characteristics, might be expected to show a higher content of phosphorus.

The relationships between phosphorus content and texture are, however, undoubtedly the most distinct. The Webster silty clay loam is higher than the loam, the Carrington loam is higher than the sandy loam and fine sandy loam but lower than the silt loam. The Lindley loam and very fine sandy loam show very slight differences. No comparisons among the loess soils can be made as the types mapped are all silt loams. On the terraces the Buckner loam is higher than the fine sandy loam. On the bottoms the Wabash silty clay loam is higher than the other Wabash types. The evidence supplied by these analyses confirms previous observations which have shown that fine textured types are generally better supplied with phosphorus than coarse textured ones. Thus silty clay loams are richer in this constituent as a rule than silt loams, loams and sandy loams. Silt loams are usually better supplied than sandy types and frequently loams are higher in phosphorus than sandy or fine sandy types of the same series.

Considering the analyses of all of these soils it may be concluded that the phosphorus supply of the soils of Hardin county is inadequate to keep crops properly supplied with phosphorus indefinitely. It seems evident that phosphorus fertilizers will be needed on all of these soils in the near future and indeed it looks quite probable that these materials might be used with profit at the present time. The total content of phosphorus in a soil does not necessarily indicate how well or how poorly plants will be supplied with the element. The amount changed to an available form determines whether or not the proper amount will be supplied for plant growth. The analyses give only the total content and if the figures show a large amount there still would be no evidence that phosphorus fertilizers would not prove of value. But where the total content is low, as in this county, there is every reason to conclude that the amount of available phosphorus produced in the soils will be much more definitely re-

duced and it would seem that phosphorus fertilizers would certainly be needed. The evidence from greenhouse and plot experiments carried out in the county and in adjacent counties on similar soils indicate that considerable profit may be secured by the proper use of a phosphorus fertilizer. Farmers are urged to test acid phosphate and rock phosphate on their own soils and determine the possible profit from the use of one or the other of these phosphorus fertilizers.

The soils of the county vary even more widely in nitrogen than in phosphorus. They range from 1,080 pounds per acre in the Carrington fine sandy loam up to 12,120 pounds in the Clyde silty clay loam. Several of the soils are quite low in nitrogen and a few are apparently very well supplied. In general there does not seem to be any striking deficiency in nitrogen in the more extensive soil areas. Only in the case of a few of the minor types, like the sandy loam and fine sandy loam in the Buckner series, is the content of nitrogen so low that additions of nitrogen are very necessary for crop growth. There seems to be little relation between the content of nitrogen in the soils of the various groups, altho the bottomland group averages slightly higher than the others. This is due largely to the fact that the bottomland soils are heavier in texture and all represent series which are characterized by considerable amounts of organic matter and nitrogen. Bottomland soils, of course, are generally expected to be somewhat higher than upland cultivated types in nitrogen as well as in other plant food constituents because generally there has been less crop growth and less removal of plant food constituents.

There is some relationship between the nitrogen content of the soils and the soil series, very much the same relationships being apparent as were noted with the phosphorus. Thus the Webster and Clyde soils are higher than the other upland drift types. The Carrington and Clarion are better supplied than the Lindley types. The Muscatine is richer than the Tama on the loessial upland, while the latter soils surpass the Clinton and Fayette in nitrogen. The Bremer and Fargo are the highest among the terrace types, while the Buckner and O'Neill are the lowest in nitrogen. The Lamoure soils seem to be better supplied than the Wabash on the bottoms.

The relations to texture are also quite distinct in the case of nitrogen. The Carrington silt loam is higher than the loam which is much better supplied than the sandy loam and the latter in turn is richer than the fine sandy loam. The Wabash silty clay loam is better supplied than the clay loam which in turn is richer than the loam. The one exception to this definite relation between nitrogen content and texture is found in the case of the Lindley loam which is lower than the very fine sandy loam, probably due to some abnormality in the particular sample of the very fine sandy loam. In general the results bear out previous observations to the effect that the nitrogen content of soils varies with certain characteristics which distinguish the soil series, particularly color, topography, origin and subsoil characteristics. Variations are also closely allied with textural differences and fine textured types are generally very much better supplied than coarse textured sandy soils.

It is apparent from these analyses that some of the soils in the county need nitrogen now, but none of the types are so well supplied that the element can be disregarded in planning systems of permanent fertility. If the supply of nitrogen

is to be kept up the system of management followed must include the supplying of some nitrogenous fertilizing material.

Farm manure is a most important nitrogenous fertilizer and it is a valuable aid in maintaining the nitrogen supply of the soil. It returns to the land a large part of the nitrogen removed from soils by the crops grown and fed on the farm. Liberal additions of farm manure, which has been properly cared for before application, will aid in a very large way in keeping up the nitrogen content of soils and will serve also to build up the supply in soils which are deficient. The proper use of crop residues will also aid in keeping up the nitrogen content in soils and such materials may be considered as serving in part as nitrogenous fertilizers.

Leguminous crops when turned under as green manures are the most important natural nitrogenous fertilizers. When inoculated, legumes have the ability of taking a large part of their nitrogen from the atmosphere, and hence they supply considerable amounts to the soil.

There is a wide variation in the organic carbon content of the Hardin county soils, the amounts present ranging from 16,926 pounds per acre in the Carrington fine sandy loam up to 130,057 pounds in the Clyde silty clay loam. These are the same types which showed the lowest and highest amount of nitrogen. The relationships between the various soils and their organic carbon content are very largely similar to those noted in the case of nitrogen. Thus the Webster and Clyde soils are higher than the other upland types. The Muscatine soils are richer than the other loessial uplands. The Bremer and Fargo soils are the highest among the terrace types, while the Lamoure are the highest on the bottomlands. The relationships to texture are also evident, the Webster silty clay loam being richer than the loam, the Carrington silt loam better supplied than the loam which is higher in turn than the sandy loams. The Buckner loam surpasses the fine sandy loam, and the Wabash silty clay loam is higher than the silt loam which in turn is better supplied than the loam.

Apparently again the soil characteristics which serve to distinguish series and types are as closely related to organic carbon or organic matter content as noted in the case of nitrogen. Soils which are black in color, level in topography, poorly drained and with heavy subsoils and heavy textured surface soil are generally much higher in organic carbon and also in nitrogen. On the other hand, coarse textured types, light in color, rolling in topography and with light textured subsoils are almost sure to be poorly supplied with these constituents.

The relation between the carbon and nitrogen present in soils indicates how rapidly plant food is being changed into an available form. In many of the soils in Hardin county the relations shown give evidence of inadequate decomposition processes and hence there is a slow production of available constituents. On these types the application of farm manure is of particularly large value, supplying as it does the agencies which bring about more rapid decomposition and a stimulation in the availability of plant food.

The use of farm manure is, however, of large value on all of the types in the county and brings about large crop increases. Even where the supply of organic matter is not low and the color of the soil is dark, farm manure proves profit-

able. It is a very important fertilizer for use in maintaining the organic matter supply in soils. Crop residues should always be utilized in order to aid in maintaining the organic matter content of soils and the use of leguminous green manures is often very desirable. The latter materials are needed especially where farm manure is not available for use. They are frequently needed also for use as supplements to the farm manure.

Only two of the soil types in the county show any inorganic carbon in the surface soil and these are the only types which are not acid in reaction. The Clarion loam on the upland and the Lamoure silty clay loam on the bottomland contain some lime, and the amount present is sufficiently large, taking into account the supply in the lower soil layers of these types, so that there is no immediate need for lime on these soils. In all of the other types in the county, however, the surface soils are acid and show some lime requirement. In one or two instances there is some lime in the subsoil, but in most cases the acidity extends thruout the subsoil. Even where there is some lime in the subsoil, acidity in the surface soil means a need for lime if legume growth is to be the most satisfactory.

TABLE V. PLANT FOOD IN HARDIN COUNTY, IOWA, SOILS.

Pounds per acre of four million pounds of subsurface soil (6⅔"—20")

Soil No.	Soil type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
	DRIFT SOILS					
1	Carrington loam	1,633	4,666	49,357	0	6,000
138	Clarion loam	2,128	6,560	52,453	35,562	0
107	Webster silty clay loam	2,019	5,000	57,384	0	2,000
55	Webster loam	2,612	5,760	64,522	29,062	0
83	Carrington silt loam	1,938	5,600	72,618	0	7,000
65	Lindley loam	2,020	1,200	17,362	0	3,000
137	Lindley very fine sandy loam	1,480	2,080	21,184	0	7,000
85	Clyde silty clay loam	3,960	5,760	78,096	0	2,000
4	Carrington fine sandy loam	1,320	960	15,615	0	4,000
3	Carrington sandy loam	1,588	2,240	30,576	0	7,000
	LOESS SOILS					
120	Tama silt loam	2,329	6,240	67,157	0	8,000
80	Clinton silt loam	1,830	2,640	26,972	0	3,000
163	Fayette silt loam	1,992	5,360	59,623	0	8,000
30	Muscatine silt loam	1,266	5,200	61,588	0	5,000
	TERRACE SOILS					
108	O'Neill loam	1,292	4,080	44,226	0	8,000
38	Buckner loam	1,588	2,960	30,685	0	4,000
75	Waukesha silt loam	1,830	6,880	79,279	0	8,000
188	Millsdale loam	2,532	7,920	90,854	0	4,000
109	Fargo silty clay loam	2,128	6,080	97,068	0	4,000
45	Buckner fine sandy loam	1,562	2,240	23,368	0	6,000
43	Bremer silty clay loam	1,104	5,040	62,025	0	4,000
	SWAMP AND BOTTOMLAND SOILS					
49	Wabash loam	2,046	4,720	43,461	0	3,000
111	Lamoure silty clay loam	2,908	8,880	87,772	34,422	0
26	Wabash silt loam	3,150	10,000	120,556	0	3,000
48	Wabash silty clay loam	1,884	6,160	67,813	0	3,000

The amount of lime needed by the various soils in the county is variable but the figures given in the table should be considered merely to indicate rough comparisons and not to show definitely the needs of all soils of the same types. The lime requirement of soils varies widely even within the same type and tests of every individual soil or from each particular field are necessary if the limestone requirement is to be determined very accurately.

It is apparent from the tests reported that the soils of Hardin county with the two exceptions mentioned should all be tested for lime requirement or acidity and if these soils are to be most satisfactorily productive, lime must be provided as called for by the tests. Furthermore, as lime disappears rapidly from soils which are under cultivation, it is necessary to test the soils at regular intervals in order to keep up the supply. Additions of lime to acid soils are always profitable and increase the growth not only of legumes but often of other farm crops. Lime should be added to most of the soils of Hardin county as needed in order to permit of the best crop growth.

TABLE VI. PLANT FOOD IN HARDIN COUNTY, IOWA, SOILS

Pounds per acre of six million pounds of subsoil (20″—40″)

Soil No.	Soil type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
	DRIFT SOILS					
1	Carrington loam	2,410	3,800	47,610	0	4,000
138	Clarion loam	2,787	6,600	46,460	90,360	0
107	Webster silty clay loam	2,544	4,200	71,498	2,868	2,000
55	Webster loam	3,231	4,080	24,372	157,773	0
83	Carrington silt loam	2,262	3,720	52,907	0	5,000
65	Lindley loam	3,069	840	19,000	0	3,000
137	Lindley very fine sandy loam	2,586	2,400	41,277	0	8,000
85	Clyde silty clay loam	3,960	3,960	74,773	0	0
4	Carrington fine sandy loam	1,695	1,200	14,250	0	5,000
3	Carrington sandy loam	1,938	960	38,656	0	2,000
	LOESS SOILS					
120	Tama silt loam	2,868	5,820	56,834	0	7,000
80	Clinton silt loam	3,150	2,760	33,579	0	3,000
163	Fayette silt loam	2,745	4,200	48,321	0	8,000
30	Muscatine silt loam	1,818	4,800	62,737	0	5,000
	TERRACE SOILS					
108	O'Neill loam	1,413	2,160	26,208	0	5,000
38	Buckner loam	2,181	3,000	36,363	0	4,000
75	Waukesha silt loam	1,938	7,080	82,227	0	8,000
188	Millsdale loam	*	.....	.....	.....	.....
109	Fargo silty clay loam	3,273	3,720	81,572	0	2,000
45	Buckner fine sandy loam	1,899	840	14,086	0	5,000
43	Bremer silty clay loam	1,695	3,240	45,045	0	3,000
	SWAMP AND BOTTOMLAND SOILS					
49	Wabash loam	3,231	6,240	73,382	0	2,000
111	Lamoure silty clay loam	3,798	7,200	92,287	20,079	0
26	Wabash silt loam	3,798	13,500	180,999	0	3,000
48	Wabash silty clay loam	3,756	3,360	50,614	0	2,000

*Not sampled.

THE SUBSURFACE SOILS AND SUBSOILS

Tables V and VI give the results of the analyses of the subsurface soils and subsoils. These are calculated on the basis of four million pounds of subsurface soil and six million pounds of subsoil per acre.

The amount of plant food in the lower soil layers has little effect upon the fertility of the soil unless there is a very large amount of some constituent present or a striking deficiency. Usually therefore, the analyses of the surface soil indicates quite accurately the plant food content and crop producing power of the soils. The lower soil layers in Hardin county are not particularly high in any constituent nor are they noticeably lacking.

An examination of the tables will reveal that the analyses merely confirm the conclusions reached in the discussion of the surface soils. Phosphorus fertilizers will certainly be necessary in the future and they might prove valuable in some cases at the present time. The content of organic matter and nitrogen must be maintained in all of the soils and in some cases it should be increased. This may be accomplished thru the proper use of farm manure, crop residues and leguminous green manures. In one or two cases there is a content of lime in the lower soil layers where the surface soil is acid, but this does not change the need of lime on the surface soils for the best early growth of legumes. It merely means that small amounts of lime will be needed and perhaps additions will be less frequently required. Thus the Webster soils show some lime in the subsoil and the Webster loam contains lime in the subsurface layer. These soils, therefore, will not require so much lime nor so frequent applications. All of the soils in the county, however, should certainly be tested for acidity and the amount of lime, which the test shows to be necessary, should be applied if the best growth of crops is to be secured. It is important also that the soils be tested regularly in order to keep up the supply of lime.

GREENHOUSE EXPERIMENTS

Two greenhouse experiments were carried out on soils from Hardin county in order to determine their fertilizer needs and the value of the application of certain materials. These tests were carried out on the Carrington loam and the Tama silt loam, the two most extensive soil types in the county. Experiments are also included on the Carrington loam and Tama silt loam from Marshall county, on the Webster silty clay loam from Wright county and the Webster loam from Hamilton county, as these soils are the same as those in Hardin county and the results secured indicate quite definitely the effects of the same fertilizer treatments on the particular soils in Hardin county.

The fertilizer treatments employed were the same in all of the experiments, including the application of manure, lime, rock phosphate, acid phosphate and a complete commercial fertilizer. These materials were added in the amounts in which they are applied in the field and hence the results serve to indicate what the fertilizer effects may be on the farm. Manure was added at the rate of 8 tons per acre, lime was supplied in amounts sufficient to neutralize the acidity and supply two tons additional, rock phosphate was added at the rate of 2,000 pounds per acre, acid phosphate at the rate of 200 pounds per acre and a

Fig. 2. Wheat and clover on Carrington loam, Hardin county.

standard 2-8-2 complete commercial fertilizer at the rate of 300 pounds per acre. Wheat and clover were grown, the clover being seeded about one month after the wheat was up. In the tests on the soils from Hardin county only the wheat yields are given as the clover yields were not secured. On the Webster silty clay loam from Wright county only the green weight of the clover was obtained, the wheat yield not being secured.

RESULTS ON CARRINGTON LOAM

The results of the experiment on the Carrington loam from Hardin county are given in table VII, the figures being the averages of the weights of the wheat grain in grams on the duplicate pots. The application of manure brought about a distinct increase in the wheat. Lime with the manure had some additional effect, and the phosphates and complete commercial fertilizer brought about still further gains. The rock phosphate had only a slight effect but the acid phosphate gave a very pronounced increase. The complete commercial fertilizer showed slightly less effect than the acid phosphate but more than the rock phosphate.

TABLE VII. GREENHOUSE EXPERIMENT.
Carrington Loam—Hardin County.

Pot No.	Treatment	Weight of wheat grain in grams
1	Check	5.223
2	Manure	8.295
3	Manure+lime	8.712
4	Manure+lime+rock phosphate	8.840
5	Manure+lime+acid phosphate	9.420
6	Manure+lime+complete commercial fertilizer	9.307

TABLE VIII. GREENHOUSE EXPERIMENT.
Tama Silt Loam—Hardin County.

Pot No.	Treatment	Weight of wheat grain in grams
1	Check	8.203
2	Manure	9.372
3	Manure+lime	10.897
4	Manure+lime+rock phosphate	12.280
5	Manure+lime+acid phosphate	12.800
6	Manure+lime+complete commercial fertilizer	11.459

Apparently this particular soil will respond to applications of manure, lime and phosphorus. The addition of manure seems to be of particularly large value, lime shows an effect even on wheat and would certainly have a much larger effect on a legume like clover. Acid phosphate seems to be somewhat superior to the rock phosphate but definite conclusions should not be drawn from one test. It is quite evident, however, that some phosphate fertilizer should be employed on this soil and that profitable results may be secured from the use of one or the other of the two phosphate fertilizers. The complete commercial fertilizer has less effect than the acid phosphate and apparently would not be as desirable for use.

RESULTS ON THE TAMA SILT LOAM

The results secured on the Tama silt loam from Hardin county appear in table VIII. The beneficial effect of manure on this soil was quite clearly shown and the large influence of lime is apparent. The material gave a considerable

Fig. 3. Greenhouse experiment with clover on Tama silt loam, Hardin county.

Fig. 4. Wheat and clover on Carrington loam, Marshall county.

increase in the yield of wheat which is rather surprising as wheat is not particularly sensitive to acidity in soils and lime usually shows the largest effect on the legume crops. The rock phosphate, the acid phosphate and the complete commercial fertilizer all increased crop yields, the phosphates showing larger effects than the complete commercial fertilizer. The acid phosphate seemed to be slightly superior to the rock phosphate but the differences were not extremely large and definite conclusions regarding the relative value of these two materials should not be drawn.

The results show that manure is a valuable material for this soil and that the addition of lime may bring about large crop increases even of non-legumes. Phosphorus fertilizers will undoubtedly prove of value and either acid phosphate or rock phosphate should certainly be employed. The use of a complete commercial fertilizer is probably less desirable than the acid phosphate.

RESULTS ON CARRINGTON LOAM FROM MARSHALL COUNTY

The results secured on the Carrington loam from Marshall county are given in table IX. The beneficial effect of manure is shown in this experiment both on the wheat crop and on the clover, large increases being secured in both cases.

TABLE IX. GREENHOUSE EXPERIMENT, CARRINGTON LOAM, MARSHALL COUNTY.

Pot No.	Treatment	Weight of wheat grain in grams	Weight of clover in grams
1	Check	16.5	22.68
2	Manure	24.0	45.36
3	Manure+lime	25.0	40.82
4	Manure+lime+rock phosphate	27.0	49.89
5	Manure+lime+acid phosphate	27.5	54.43
6	Manure+lime+complete commercial fertilizer	26.0	49.89

TABLE X. GREENHOUSE EXPERIMENT, TAMA SILT LOAM, MARSHALL COUNTY.

Pot No.	Treatment	Weight of wheat grain in grams	Weight of clover in grams
1	Check	19.75	45.36
2	Manure	23.00	45.36
3	Manure+lime	23.50	49.89
4	Manure+lime+rock phosphate	24.00	54.43
5	Manure+lime+acid phosphate	27.50	72.63
6	Manure+lime+complete commercial fertilizer	24.00	63.50

In fact the clover yield was doubled. Lime had a small effect on the wheat but showed no increase on the clover. This is surprising, as lime usually shows its largest effect on the legume. Evidently there was some disturbing factor occurring in this particular case so that no increase was secured. This soil ordinarily shows a large response to lime. The phosphates and the complete commercial fertilizer all gave distinct increases in yields of wheat and clover. With the former crop very little difference in effects were evident. With the clover, however, the acid phosphate seemed somewhat superior.

These results very largely confirm those secured in Hardin county in showing the beneficial effects of manure, lime and phosphate fertilizers. Again it would seem that acid phosphate is somewhat more profitable than the rock. Results indicate also that the complete commercial fertilizer is less profitable for use than the acid phosphate.

RESULTS ON THE TAMA SILT LOAM FROM MARSHALL COUNTY

Results secured on the Tama silt loam from Marshall county are given in table X. Manure brought about a distinct effect on the wheat grown on this

Fig. 5. Greenhouse experiment with clover on Tama silt loam, Marshall county.

TABLE XI. GREENHOUSE EXPERIMENT, WEBSTER SILTY CLAY LOAM, WRIGHT COUNTY.

Pot No.	Treatment	Weight green clover in grams
1	Check	61.23
2	Manure	108.86
3	Manure+lime	127.00
4	Manure+lime+rock phosphate	140.61
5	Manure+lime+acid phosphate	131.54
6	Manure+lime+complete commercial fertilizer	124.74

soil but had little influence on the clover. Lime in addition to manure increased the wheat very slightly but showed a distinct increase on the clover. It would naturally be expected that this crop would show the larger influence. Rock phosphate had a small effect on the wheat but showed a distinct increase on the clover. Acid phosphate gave a larger effect than the rock on both crops, the increase being particularly large in the case of the clover. The complete commercial fertilizer showed less effect than the acid phosphate on both crops but had a slightly larger effect than the rock phosphate on the clover.

RESULTS ON THE WEBSTER SILTY CLAY LOAM FROM WRIGHT COUNTY

The results secured on the Webster silty clay loam from Wright county are given in table XI, only the green weights of the clover being recorded. The application of manure to this soil brought about large increases in the clover. Lime with the manure proved of considerable value and the phosphates gave further increases. The rock phosphate showed a somewhat greater effect than the acid phosphate, and both materials showed more influence than the complete commercial fertilizer. Apparently this soil, tho high in organic matter, will respond to applications of farm manure. Additions of lime to the surface soil when it is acid may give considerable crop increases. The addition of a phosphate fertilizer may prove distinctly profitable. Tests of the use of acid phosphate and rock phosphate are recommended in order that the material most desirable for use may be employed.

Fig. 6. The effect of various fertilizers on clover grown on Webster loam from Hamilton county.

TABLE XII. GREENHOUSE EXPERIMENT, WEBSTER LOAM, HAMILTON COUNTY.

Pot No.	Treatment	Weight of wheat grain in grams	Weight of clover in grams
1	Check	13.15	59.5
2	Manure	13.77	....
3	Manure+lime	17.61	70.0
4	Manure+lime+rock phosphate	13.94	74.5
5	Manure+lime+acid phosphate	18.01	80.0
6	Manure+lime+complete commercial fertilizer	20.31	82.0

Experiments on this type in Hardin county are confirmed by these data as it is clearly shown that manure is of large value on this soil, applications of lime will also prove profitable and a phosphate fertilizer should certainly be used. Acid phosphate appears somewhat preferable but tests in the field are recommended before there is any application to an extensive area. Apparently a complete commercial fertilizer is of less value than acid phosphate.

RESULTS ON THE WEBSTER LOAM FROM HAMILTON COUNTY

The results secured on the Webster loam from Hamilton county are given in table XII. The addition of manure gave some increase in the wheat crop but the yield of clover on the manured pot was not secured. Lime in addition to manure increased the wheat yield considerably. The combination of lime and manure showed a large increase in the clover. Acid phosphate increased the yields of both crops quite definitely. Rock phosphate, however, showed little effect on the wheat and only a small gain in the clover. The complete fertilizer showed slightly larger effects on both crops than the acid phosphate.

It is apparent from these results that manure may prove of value on this type, that lime should be used when the surface soil is acid in order to secure the best crop growth and that a phosphate fertilizer may prove distinctly profitable. Acid phosphate seems to be somewhat preferable but the results are not definite enough to be conclusive. The complete commercial fertilizer had only a slightly larger effect than the acid phosphate and hence would be less profitable for use.

FIELD EXPERIMENTS

Field experiments have been under way in Hardin county for several years, on the Eldora field. The results secured in these tests will be discussed here inasmuch as they indicate the fertilizer needs of the Carrington loam, the most extensive soil type in Hardin county. Other field experiments are under way in adjacent counties on other types and these will be included here as they show quite clearly the results which may be secured in this county. Experiments on the Carrington loam on the Waverly field in Bremer county, on the Tama silt loam on the Hudson field in Black Hawk county, and on the Webster loam on the Lundgren field in Webster county are included, along with those on the Carrington loam in two series on the Eldora field in Hardin county. Average results secured on the Carrington loam and on the Tama silt loam on all the fields on those types in the state are also given.

These field experiments are all planned in order to determine the value of various soil treatments and they are laid out on land which is representative of

the particular soil types. The fields include 13 plots, 155 feet 7 inches by 28 feet, or one tenth of an acre in size. They are permanently located by the installation of corner stakes and all precautions are taken in applying fertilizers and harvesting the crops to secure accurate results.

The fields include tests under the livestock system of farming and under the grain system. In the former system manure is applied while in the latter, crop residues are employed. The other fertilizing materials which are tested include limestone, rock phosphate, acid phosphate and a complete commercial fertilizer. Manure is applied at the rate of 8 tons per acre once in a four year rotation. The crop residues treatment consists of plowing under the corn stalks which have been cut with a disc or stalk cutter, turning under the straw from the small grains and the plowing under of at least the second crop of clover. Sometimes the first crop of clover is cut and allowed to remain on the land to be plowed under with the second. Lime is applied in sufficient amounts to neutralize the acidity of the soils and supply 2 tons additional. Rock phosphate is added at the rate of 2,000 pounds per acre in a four year rotation. Acid phosphate is employed at the rate of 200 pounds per acre annually. Until 1923, the old standard 2-8-2 complete commercial fertilizer was used, application being made at the rate of 300 pounds per acre annually. The new standard 2-12-2 brand is now applied at the rate of 267 pounds per acre annually, thus supplying the same amount of phosphorus as that contained in the 200 pounds of acid phosphate.

THE ELDORA FIELD

The results secured on the Carrington loam in Hardin county on the Eldora field, series 100, are given in table XIII. This experiment was begun in 1915 and the results have now been secured for nine years. The regular four-year rotation is practiced and yields have been secured for five crops of corn, two crops of oats and two of clover. The application of manure has increased the crop yields in practically all cases. The results the first year were somewhat abnormal and no increase appeared. The yields of corn in 1918, 1919 and 1922 were very much increased by the manure. The oats showed distinct gains and the crop yield was increased considerably particularly in 1921. The addition of lime with manure increased the clover yield in 1917 and showed some effects on the corn and oats yields in other years but no large gains were noted. The rock phosphate and acid phosphate gave large increases in the yields of all of the crops, with the exception of the rock phosphate on the corn in 1922 and 1923. The effect of the two phosphates on the clover in 1921 was particularly pronounced. The acid phosphate showed an unusually large effect on the corn in 1918, it also gave large effects on the oats in 1916 and on the corn in 1919 and 1922. In general, the acid phosphate showed much more pronounced effects than the rock phosphate. The complete commercial fertilizer showed larger effects than the acid phosphate on the clover in 1917 and 1921 and on the corn in 1923. The differences, however, were not very large in any of these cases and in several instances the increases were smaller than those brought about by the acid phosphate.

The crop residues showed little effect on the various crops grown, small increases being noticed in a few instances. The lime showed some increases, hav-

TABLE XIII. FIELD EXPERIMENT—CARRINGTON LOAM—HARDIN COUNTY.

Eldora Field—Series 100.

Plot No.	Treatment	1915 Corn Bu. per acre	1916 Oats Bu. per acre	1917 Clover Tons per acre	1918 Corn Bu. per acre	1919 Corn Bu. per acre	1920 Oats Bu. per acre	1921 Clover Tons per acre	1922 Corn Bu. per acre	1923 Corn Bu. per acre
1	Check	47.5	40.0	1.19	46.4	33.9	42.8	1.75	64.3	41.5
2	Manure	38.5	50.0	1.36	55.8	52.5	49.6	1.65	67.2	40.0
3	Manure+lime	40.8	40.0	1.53	52.2	50.6	56.9	1.50	69.9	38.2
4	Manure+lime+rock phosphate	53.3	46.0	1.78	48.9	58.8	57.7	2.30	66.4	41.8
5	Manure+lime+acid phosphate	53.9	53.0	1.87	68.8	61.1	60.3	2.55	73.6	44.8
6	Manure+lime+complete commercial fertilizer	52.2	53.6	2.04	60.7	57.9	59.8	2.65	70.7	50.4
7	Check	35.3	33.8	1.44	56.8	35.4	43.1	1.40	61.7	34.9
8	Crop residues	37.2	33.9	1.36	53.3	39.6	38.7	1.40	62.2	33.0
9	Crop residues+lime	37.3	30.0	1.28	60.3	39.2	50.2	1.55	64.3	41.5
10	Crop residues+lime+ rock phosphate	38.7	33.3	1.70	62.2	44.0	52.2	2.40	73.6	45.6
11	Crop residues+lime+ acid phosphate	46.8	46.6	1.87	65.3	46.0	55.7	3.00	82.2	43.9
12	Crop residues+lime+ complete commercial fertilizer	35.0	50.0	1.70	63.7	41.6	67.2	2.85	70.0	45.9
13	Check	28.8	33.8	1.23	58.3	35.0	39.4	2.00	65.0	38.2

ing the most pronounced effect on the oats in 1920 and on the clover in 1921. The corn in 1923 also showed a considerable increase. The rock phosphate and acid phosphate gave large crop increases in practically all cases. Again the effect was the greatest on the clover in 1921. The corn in 1922 was also increased to a very large extent. The acid phosphate gave larger increases than the rock phosphate every year except 1923. In several cases, the gains over rock phosphate were very pronounced. The complete commercial fertilizer showed larger effects than the acid phosphate in three cases, having a very pronounced effect on the oats in 1920. In most years, however, the acid phosphate proved superior.

The yields secured on series 200 of the Eldora field are recorded in table XIV. The yields on this field have been secured since 1917 and there are records for seven crops. The manure gave a large increase in the yields of all of the crops except the corn in 1923. The effects on the oats in 1921 and on the clover in 1922 were pronounced. The addition of lime with the manure gave further increases in crop yields in most cases. The increases were not large but were rather distinct. The rock phosphate and acid phosphate proved of large value on all of the crops grown, the increases being particularly noticeable on the clover in 1922. The acid phosphate proved superior to the rock phosphate on four of the crops while the rock surpassed it in three cases. The complete commercial fertilizer gave a larger effect than the acid phosphate in 1921, 1922 and 1923, but had less effect in the first four years of the test. The differences were hardly large enough on the average therefore to warrant preference being given to the complete fertilizer.

TABLE XIV. FIELD EXPERIMENT—CARRINGTON LOAM—HARDIN COUNTY.

Eldora Field—Series 200.

Plot No.	Treatment	1917 Oats Bu. per acre	1918 Clover Tons per acre	1919 Corn Bu. per acre	1920 Corn Bu. per acre	1921 Oats Bu. per acre	1922 Clover Tons per acre	1923 Corn Bu. per acre
1	Check	60.1	0.54	46.4	60.9	26.6	1.17	41.5
2	Manure	66.4	0.90	50.0	62.5	38.0	1.38	37.6
3	Manure+lime	65.7	1.00	51.8	65.6	41.8	1.31	40.0
4	Manure+lime+rock phosphate	72.6	1.85	53.6	71.8	50.3	2.06	42.1
5	Manure+lime+acid phosphate	85.5	1.51	57.2	68.7	48.7	2.57	46.6
6	Manure+lime+complete commercial fertilizer	80.0	1.48	51.7	59.3	54.6	2.61	53.2
7	Check	62.0	0.45	48.8	42.1	36.9	1.88	38.2
8	Crop residues	61.8	0.41	50.7	35.9	32.3	1.80	36.9
9	Crop residues+lime	63.0	0.47	50.8	35.9	29.2	1.41	43.2
10	Crop residues+lime+rock phosphate	69.2	0.49	60.0	45.3	22.0	2.13	40.5
11	Crop residues+lime+acid phosphate	67.6	0.74	62.5	48.4	32.2	2.32	40.0
12	Crop residues+lime+complete commercial fertilizer	66.4	0.51	55.3	59.3	37.2	2.60	46.6
13	Check	60.0	0.38	52.1	48.4	28.6	1.68	31.5

The crop residues showed little effect on the crop yields in most cases, the yields secured being practically the same as those on the check plot. The addition of lime gave increases in most cases. The yield on plot 9 in 1922 was evidently abnormal, as clover usually responds quite definitely to the use of lime. The rock phosphate and acid phosphate gave distinct increases in crop yields except in 1921 and 1923. The yields were increased to a large extent in 1922. The complete commercial fertilizer showed a somewhat larger effect than the acid phosphate thru the last four years of the experiment. The differences were not large, however, except on the corn in 1920.

The results on this field indicate quite clearly the beneficial effect of the application of manure, lime and phosphorus to the Carrington loam. Large increases in crop yields result from the use of manure. The application of lime proved of value in most cases. The application of acid phosphate proved profitable in many cases and rock phosphate often gave considerable crop increases. The soluble acid phosphate seems profitable for use according to these data but further results are necessary before definite conclusions should be drawn. The complete commercial fertilizer often gave considerable increases in crop growth but in general the acid phosphate seems to give quite as large increases and therefore would prove more profitable.

THE WAVERLY FIELD NO. I

The results secured on the Waverly field, No. I, on the Carrington loam in Bremer county are shown in table XV. This experiment was started in 1917 and results have been secured for six years. Manure increased the yields of all of the crops grown except the oats in 1923, proving of considerable value, however, on the oats in 1918 and on the clover in 1919. The application of lime with the manure increased the clover in 1919 and the corn in 1922. In

the other years no increases were noted. The rock phosphate and acid phosphate gave large increases in crop yields in all cases. The largest increases were secured on the oats in 1918, the clover in 1919 and the corn in 1920 and 1922. Acid phosphate gave larger increases than the rock phosphate in four cases showing slightly smaller effects on the oats in 1918 and 1921. The complete commercial fertilizer showed less effect than the acid phosphate except in 1922 and 1923, in the latter year being very slightly superior to the acid phosphate.

The crop residues gave small increases in crop yields in one or two cases but in general had little effect. The application of lime proved of value on all of the crops. Each year considerable increases were secured, the effect being the most pronounced on the corn in 1920 and 1922. Such beneficial effects of lime on corn are not frequent as this crop does not ordinarily respond to any large extent to the use of lime. The rock phosphate and acid phosphate increased the crop yields in most cases. However, there was no effect on the oats in 1918 or 1921, the corn in 1922 or the oats in 1923 from the acid phosphate. Conclusions as to the relative merits of the two phosphates certainly could not be drawn from these data but taken together with the other experimental evidence it would seem that the yields on plot 11 during the last three years of the test were probably low because of the interference of some factor. The complete commercial fertilizer proved of larger effect than the acid phosphate on all of the crops except the oats in 1918. The increases from the use of the complete commercial fertilizer were not large, however, except on the clover in 1919 and the corn in 1920.

These results serve to confirm to a very large extent the conclusions drawn from the experiments on the Eldora field. The beneficial effect of manure is very clearly shown and the value of applying lime to this soil is distinct. The use of a phosphate fertilizer seems to be of value. While a complete commercial

TABLE XV. FIELD EXPERIMENT—CARRINGTON LOAM—BREMER COUNTY.

Waverly Field—No. 1 Series I.

Plot No.	Treatment	1918 Oats Bu. per acre	1919 Clover Tons per acre	1920 Corn Bu. per acre	1921 Oats Bu. per acre	1922 Corn Bu. per acre	1923 Oats Bu. per acre
1	Check	46.6	1.40	85.3	36.8	54.9	32.8
2	Manure	57.2	1.84	89.0	38.9	57.6	31.7
3	Manure+lime	49.1	2.02	87.8	35.4	60.5	29.4
4	Manure+lime+rock phosphate	67.0	2.10	94.0	46.5	64.1	34.0
5	Manure+lime+acid phosphate	62.5	3.10	101.5	45.2	74.9	37.3
6	Manure+lime+complete commercial fertilizer	58.5	2.84	94.2	40.7	81.0	38.3
7	Check	50.4	1.48	83.8	33.5	61.1	34.0
8	Crop residues	52.6	1.90	81.6	35.3	60.8	27.2
9	Crop residues+lime	57.2	1.94	96.3	42.4	73.6	30.6
10	Crop residues+lime+rock phosphate	50.7	2.32	97.8	48.6	70.6	36.3
11	Crop residues+lime+acid phosphate	56.8	2.52	101.0	37.7	64.5	29.4
12	Crop residues+lime+complete commercial fertilizer	48.1	2.68	104.5	45.8	78.1	35.2
13	Check	48.9	1.56	84.3	34.7	59.2	31.7

fertilizer proved of value in some cases, in general, it seemed to have a less profit able effect than the phosphates.

THE WAVERLY FIELD NO. II

The results secured on the Waverly field, No. II, series I, in Bremer county are given in table XVI. This experiment was started in 1917, and the yields have been secured for five years. In 1923, owing to severe drought, crop weights were not secured. The application of manure increased crop yields considerably each year except in 1922 when the clover showed no influence. The oats in 1918 and the clover in 1919 gave very large increases from the use of manure. Lime in addition to manure increased the crops each year except in 1919 when the yield was extremely abnormal on plot three, as no decrease in crop should have occurred. The oats in 1921 on plot three gave also an extremely abnormal yield as it was very high, much above that on any of the other plots in the series. In general, the lime showed the usual increase in the various crops. The rock phosphate and acid phosphate increased the yields in all except one case, altho there is some question about the result in 1921 owing to the abnormality of plot three already referred to. The rock phosphate had little effect on the clover in 1922 but the acid phosphate proved of large value that year. In general the acid phosphate gave larger effects than the rock phosphate altho in several cases the differences were not very distinct. The increases secured on the clover in 1919 from both phosphates were particularly large. The complete commercial fertilizer had less effect than the acid phosphate every year except in 1918. In several cases it showed less effect than the rock phosphate.

The crop residues showed no effect on the various crops grown but the addition of lime proved of value in most instances. The rock phosphate and acid phosphate both showed large crop increases which were noted particularly in 1918, 1919, 1921 and 1922. The acid phosphate was superior to the rock except on the oats in 1921 but the differences were small. The complete commercial fer-

TABLE XVI. FIELD EXPERIMENT—CARRINGTON LOAM—BREMER COUNTY.

Waverly Field—No. 2 Series I.

Plot No.	Treatment	1918 Oats Bu. per acre	1919 Clover Tons per acre	1920 Corn Bu. per acre	1921 Oats Bu. per acre	1922 Clover Tons per acre
1	Check	42.8	1.50	47.8	25.7	2.22
2	Manure	61.0	1.75	56.5	34.3	2.20
3	Manure+lime	64.9	1.10	57.5	50.6	2.32
4	Manure+lime+rock phosphate	65.5	2.60	58.0	40.3	2.10
5	Manure+lime+complete commercial fertilizer	72.1	2.35	44.0	35.7	2.78
6	Manure+lime+acid phosphate	67.2	2.85	47.0	42.0	2.90
7	Check	55.1	1.55	36.6	30.6	1.76
8	Crop residues	49.6	1.05	39.6	20.3	1.24
9	Crop residues+lime	66.2	1.50	40.8	30.4	1.84
10	Crop residues+lime+rock phosphate	70.0	1.75	41.6	40.6	2.16
11	Crop residues+lime+acid phosphate	88.2	2.55	43.3	38.4	2.70
12	Crop residues+lime+complete commercial fertilizer	88.6	2.10	45.8	46.0	2.70
13	Check	79.7	1.55	35.1	26.7	1.48

TABLE XVII. FIELD EXPERIMENT—CARRINGTON LOAM—BREMER COUNTY.

Waverly Field—No. 2 Series II.

Plot No.	Treatment	1918 Corn Bu. per acre	1919 Oats Bu. per acre	1920 Clover Tons per acre	1921 Clover & Timothy Tons per acre	1922 Corn Bu. per acre	1923 Corn Bu. per acre
1	Check	38.5	39.8	0.47	1.03	39.4	25.0
2	Manure	54.0	49.3	0.67	1.30	55.7	40.2
3	Manure+lime	56.8	61.9	1.36	1.87	62.3	57.0
4	Manure+lime+rock phosphate	57.2	46.4	1.66	1.98	63.1	62.0
5	Manure+lime+acid phosphate	60.5	57.8	2.05	2.19	64.0	60.7
6	Manure+lime+complete commercial fertilizer	61.3	61.9	1.99	2.47	62.9	63.0
7	Check	48.7	35.4	0.84	1.17	45.7	34.2
8	Crop residues	46.4	39.4	0.67	1.09	41.4	34.0
9	Crop residues+lime	50.0	48.3	0.87	1.26	50.6	45.2
10	Crop residues+lime+rock phosphate	56.7	40.8	1.14	1.44	52.0	46.5
11	Crop residues+lime+acid phosphate	48.7	47.3	1.11	1.63	51.4	47.5
12	Crop residues+lime+complete commercial fertilizer	42.7	53.5	1.32	2.10	60.8	50.7
13	Check	33.4	32.9	0.33	0.87	34.8	43.2

tilizer proved slightly more effective than the acid phosphate on the corn in 1920 and on the oats in 1921, but in the other years showed less effect.

The yields secured on series II in this field are given in table XVII. As in the other tests the application of manure proved of large value, considerably increasing the crop yields in some cases. The increases on the corn in 1918, 1922 and 1923 were particularly noteworthy. The addition of lime with the manure proved of large value on all of the crops, corn in 1923 showing the largest gain. The clover in 1920 was also benefited to a very large extent. Rock phosphate and acid phosphate increased the crop yields in all cases except on the oats in 1919. The increases were particularly noticeable on the clover in 1920. The acid phosphate gave larger increases than the rock phosphate each year except on the corn in 1923 where the difference was slight. The complete commercial fertilizer was slightly superior to the acid phosphate in several cases but the differences were generally rather small.

Crop residues had very little effect on the yields secured. Lime with crop residues increased the yields in a very definite way each year, the effect being particularly pronounced on the corn in 1923 but quite evident on all of the other crops. The rock phosphate and the acid phosphate brought about increases in crop yields thruout the last four years of the experiment but had little or no effect in 1918 and 1919. The acid phosphate was very slightly superior to the rock phosphate on only two of the crops grown during the last four years, while the rock phosphate proved a little better on the other two. Apparently the two materials had very similar effects on this particular soil. The complete commercial fertilizer gave larger effects than the acid phosphate after 1919, the increase being particularly pronounced in the case of the clover and timothy in 1921.

These experiments on the two series of plots on the Waverly field No. II, offer further confirmation of the conclusions previously reached regarding the needs of this soil. Manure is of large value, lime should be used to remedy acid conditions and a phosphate fertilizer may prove distinctly profitable. Acid phosphate may be superior to rock in some cases but the results vary under different soil conditions even on the same type and tests of the two materials are necessary in order to determine which should be employed in any particular case. The complete commercial fertilizer does not seem to give increases which are sufficiently larger than those brought about by the acid phosphate to warrant the use of the more expensive material.

THE HUDSON FIELD

The results secured on the Tama silt loam on the Hudson field in Black Hawk county are given in table XVIII. The crop yield was not secured in 1921 owing to the fact that the corn was cut and put in a silo before the field man arrived to secure the yields. The application of manure to this type increased the crop yields each year, the gains being quite pronounced. Lime with the manure brought about further crop increases, very definite value being indicated from the use of the lime. The phosphate increased the crop yields during the first three years of the test but had little effect in 1922 and 1923. The gains were quite definite in 1919 and 1920. Acid phosphate showed little superiority over the rock phosphate, the results being very close together for the two treatments. The complete commercial fertilizer had a greater effect than the acid phosphate in 1918, 1922 and 1923, showing increases on crop yields during the two latter years while the phosphates had no effect in those years.

The crop residues showed little effect on the various crops grown except on the corn in 1920. The yield on the check plot that year, however, was undoubtedly abnormal for some unknown reason as the yield was very low. The appli-

TABLE XVIII. FIELD EXPERIMENT—TAMA SILT LOAM—BLACK HAWK COUNTY.

Hudson Field.

Plot No.	Treatment	1918 Corn Bu. per acre	1919 Oats Bu. per acre	1920 Corn Bu. per acre	1921 Corn Bu. per acre	1922 Oats Bu. per acre	1923 Corn Bu. per acre
1	Check	45.8	47.6	53.2		44.8	54.0
2	Manure	49.3	54.7	62.8	Cut	53.1	59.6
3	Manure+lime	54.4	59.2	67.4	and	59.6	65.2
4	Manure+lime+rock phosphate	56.5	64.9	73.3	put	58.1	61.4
5	Manure+lime+acid phosphate	57.4	62.2	73.3	in	53.2	59.6
6	Manure+lime+complete commercial fertilizer	58.5	57.5	72.4	silo	62.2	68.4
7	Check	56.9	62.2	44.0		41.4	54.8
8	Crop residues	54.7	62.2	65.2		49.0	53.1
9	Crop residues+lime	57.9	64.6	71.3		62.4	66.7
10	Crop residues+lime+rock phosphate	62.8	58.1	74.9		59.6	65.7
11	Crop residues+lime+acid phosphate	55.6	55.8	74.9		64.4	62.8
12	Crop residues+lime+complete commercial fertilizer	52.5	57.5	74.1		71.3	62.8
13	Check	54.5	57.0	71.3		59.7	50.2

TABLE XIX. FIELD EXPERIMENT—WEBSTER LOAM—WEBSTER COUNTY.
Lundgren Field.

Plot No.	Treatment	1918 Oats Bu. per acre	1919 Corn Bu. per acre	1920 Corn Bu. per acre	1921 Oats Bu. per acre	1922 Corn Bu. per acre	1923 Oats Bu. per acre
1	Check	93.5	59.0	63.8	33.0	57.7	43.1
2	Manure	85.0	58.3	62.4	37.8	55.5	48.8
3	*Manure+lime	89.2	60.6	65.3	32.9	56.0	46.5
4	*Manure+lime+rock phosphate.	85.0	61.3	69.3	38.7	57.1	52.3
5	*Manure+lime+acid phosphate.	91.4	65.1	67.2	35.8	54.9	58.0
6	*Manure+lime+complete commercial fertilizer	89.2	65.1	74.2	36.6	57.5	62.5
7	Check	85.0	54.0	59.7	32.6	46.6	44.2
8	Crop residues (acid phosphate+potassium in 1922)	82.9	63.3	59.7	38.5	50.1	57.8
9	*Crop residues+lime	85.0	63.5	57.7	39.6	47.7	52.2
10	*Crop residues+lime+rock phosphate	87.1	65.9	68.9	31.8	51.6	52.2
11	*Crop residues+lime+acid phosphate	97.7	69.7	68.6	36.4	54.8	62.5
12	*Crop residues+lime+complete commercial fertilizer	93.5	73.9	65.2	39.9	56.1	62.5
13	Check	80.7	54.2	57.7	35.0	52.1	43.2

*No lime until November 1, 1921.

cation of lime gave considerable increases in crops each year just as was noted when the lime was applied with manure. The increase was particularly large in the oats in 1922. The rock phosphate and the acid phosphate increased the crop yields in most cases altho there was little effect during the first two years of the test. Very little difference between the value of the two phosphates was indicated by these results. The data show that sometimes one phosphate is superior and sometimes the other. The complete commercial fertilizer had a larger effect on the oats in 1922 than did the acid phosphate but in most cases the acid phosphate was slightly superior.

Apparently the Tama silt loam will respond to applications of manure and considerable increases in crop yields may be secured from the proper use of this material. The application of lime is very desirable on this type and crop yields are considerably benefited when lime is used. Phosphorus is certainly needed but the results do not show which phosphate should be employed. The increases brought about were very similar for the two materials. It does not seem that the complete commercial fertilizer is of as much value as one of the phosphates, and hence the latter seems preferable for use.

THE LUNDGREN FIELD

The results secured on the Webster loam on the Lundgren field in Webster county are given in table XIX. No lime was applied on this field until 1921, so that plots 2 and 3, and 7 and 8 were duplicates during the first three years of the test. The application of manure showed slight increases on the crops grown in several cases but no large effects were noted. The lime showed no influence on the crops in 1921 or in the succeeding years. The two phosphates increased the crop yields quite definitely, except in the case of the oats in 1918. The acid

phosphate had little effect on the oats in 1921 or the corn in 1922. In general the rock phosphate seemed somewhat superior to the acid phosphate. The differences, however, are small and probably should not be considered at all definite. The complete commercial fertilizer showed somewhat larger effects than the phosphates in 1919, 1920 and 1923, but the differences were not extremely large in any case.

The crop residues showed little effect on the crops grown, tho increases were noted in 1919 and 1921. The lime showed no effect on the crops grown after 1921. The two phosphates increased the yields in several cases, the acid phosphate proving very effective in 1918. Both phosphates had large effects in 1920 and again in 1922. In 1923, the acid phosphate proved of value but the rock phosphate had no effect. In general the acid phosphate seems somewhat superior to rock phosphate but definite conclusions along this line should not be drawn. The complete commercial fertilizer was slightly more effective than the acid phosphate in two or three cases but the differences were not large enough to show any pronounced profit from the use of the complete brand. Acid phosphate and potassium applied in 1922 to plot 8 gave distinct increases in the two crops, being particularly effective on the oats in 1923.

The Webster loam may apparently respond in a small way to applications of manure but large amounts of this material are not desirable for use on this soil, especially prior to the growth of a small grain crop, owing to the danger of causing it to lodge. Small applications may, however, be of considerable value on other crops. The soil is usually not acid but, when it is tested and found to be high in acidity, additions of lime are very desirable. The use of a phosphate fertilizer would probably prove desirable but tests should be carried out in the field on the individual farm before either one or the other material is selected for extensive application. The complete commercial fertilizer does not seem to have any large superior effect over the phosphates.

AVERAGE RESULTS ON THE CARRINGTON LOAM

Average results secured on all of the experiment fields on the Carrington loam are given in table XX. The addition of lime to this soil gave large increases in the corn, oats and clover. The use of lime with the manure was of considerable effect on all three crops. The increases were quite as definite in the case of the corn and the oats as in the case of the clover. The rock phosphate and acid phosphate brought about profitable effects on the various crops the results being very similar on the corn and oats. The acid phosphate, however, showed up much better on the clover. The complete commercial fertilizer brought about increases which were very similar to those occasioned by the phosphates on the corn and oats and it had much the same effect as the acid phosphate on the clover.

Crop residues had little influence on the crops grown but the use of lime again proved of distinct value. The two phosphates increased the crop yields, the acid phosphate proving to be superior on the corn in every instance. The complete commercial fertilizer gave slightly larger effects than the acid phosphate.

TABLE XX. CARRINGTON LOAM.

Average Crop Yields and Increases Due to Fertilizer Treatment.

Iowa Experiment Fields.

Treatment	Corn*		Oats*		Clover*	
	Average yield bu. per acre	Increase for treatment bu. per acre	Average yield bu. per acre	Increase for treatment bu. per acre	Average yield tons per acre	Increase for treatment tons per acre
Check	51.9	....	43.6	....	1.25	....
Manure	58.8	6.9	49.6	6.0	1.38	0.13
Manure+lime	62.6	10.7	53.0	9.4	1.57	0.32
Manure+lime+rock phosphate	66.0	14.1	62.3	18.7	1.97	0.72
Manure+lime+acid phosphate	66.3	14.4	60.8	17.2	2.27	1.02
Manure+lime+complete commercial fertilizer	66.8	14.9	62.4	18.8	2.29	1.04
Crop residues	54.7	2.8	47.3	3.7	1.37	0.12
Crop residues+lime	57.5	5.6	49.3	5.7	1.41	0.16
Crop residues+lime+rock phosphate	61.8	9.9	51.2	7.6	1.80	0.55
Crop residues+lime+acid phosphate	62.4	10.5	52.7	9.1	1.94	0.69
Crop residues+lime+complete commercial fertilizer	64.2	12.3	58.2	14.6	2.02	0.77

*Corn yields averaged from 20 crops on 10 fields, oats from 9 crops on 5 fields and clover from 15 crops on 9 fields.

The Carrington loam may be increased in fertility, judging from these results, by applications of manure, lime and a phosphate fertilizer. The other experiments on individual fields which have been mentioned show very similar results to these averages. Acid phosphate seemed superior to the rock phosphate but tests on individual fields are recommended before one or the other of the two fertilizers is applied extensively. The value from the complete commercial fertilizer does not seem sufficiently great to warrant its use in preference to acid phosphate.

AVERAGE RESULTS ON THE TAMA SILT LOAM

Average results from all of the field experiments in the state on the Tama silt loam are given in table XXI. The application of manure increased both corn and oat yields. Lime applied with the manure brought about increases in both of these crops. Altho rock phosphate and acid phosphate both gave increases, rock phosphate produced slightly larger effects than acid phosphate. The differences, however, are not very distinct and no conclusions regarding the relative value of the two materials should be drawn. The complete commercial fertilizer had less effect than the phosphates on corn but gave somewhat greater effects on the oats.

Crop residues had very little effect on the various crops but again the use of lime proved of large value. The phosphates produced increases in both the corn and oats, the acid phosphate proving somewhat superior to the rock phosphate. The complete commercial fertilizer again had less effect than the phosphates on corn but showed somewhat larger effects on the oats. These average figures indicate that phosphate fertilizers may be applied to the Tama silt loam with profit. Whether rock phosphate or acid phosphate should be employed can not now be definitely stated. The rock phosphate seems better in the presence of manure

TABLE XXI. TAMA SILT LOAM.

Average Crop Yields and Increases Due to Fertilizer Treatment.

Iowa Experiment Fields.

Treatment	Corn*		Oats*	
	Bu. per acre	Increase from treatment bu. per acre	Bu. per acre	Increase from treatment bu. per acre
Check	63.3	....	46.0	....
Manure	69.6	6.3	49.4	3.4
Manure+lime	71.8	8.5	56.3	10.3
Manure+lime+rock phosphate	77.7	14.4	58.6	12.6
Manure+lime+acid phosphate	75.3	12.0	56.7	10.7
Manure+lime+complete commercial fertilizer	73.7	10.4	62.9	16.9
Crop residues	69.7	6.4	47.0	1.0
Crop residues+lime	71.8	8.5	57.9	11.9
Crop residues+lime+rock phosphate	74.4	11.1	58.9	12.9
Crop residues+lime+acid phosphate	75.7	12.4	63.3	17.3
Crop residues+lime+complete commercial fertilizer	72.7	9.4	68.0	22.0

*The corn yields are the averages of 3 years results on 2 fields.
*The oats yields are the averages of 2 years results on 2 fields.

while the acid phosphate gives better effects where manure is not employed. The differences, however, are hardly large enough to be distinct. A complete commercial fertilizer may possibly be used on this type with value but tests are recommended before any complete brand is applied in a large way. It seems probable that quite as large and even more profitable results may be secured from the application of acid phosphate.

NEEDS OF HARDIN COUNTY SOILS AS INDICATED BY LABORATORY, GREENHOUSE AND FIELD TESTS

Field experiments have been under way in Hardin county at Eldora for several years. These are located on the Carrington loam, the most extensive soil type in the county, and the results which have been secured are certainly indicative of the needs of this particular soil type. Other experiments have been carried out in other counties on the same soil type or on other types which occur commonly in Hardin county. The soil treatments recommended are based on the results of these various field tests, the greenhouse tests described earlier in this report and the analytical data. These recommendations are based on practical experience as well as on experimental data and no suggestions are offered which have not been shown to be of value by practical experience.

LIMING

The soils of Hardin county are practically all acid in reaction and, therefore, in need of lime. Only two of the types mapped in the county show any content of lime in the surface soil. These are the Clarion loam on the upland and the Lamoure silty clay loam on the bottoms. In the case of the former type there are many areas where the surface soil does not contain lime altho there is a large content of lime in the lower soil layers. Some of the other types in the

county, particularly those of the Webster series, contain lime in the subsurface and subsoil layers but the surface soils of these types are apt to be slightly acid. The needs of the surface soils are considered to show most accurately the lime requirement of the particular soil. Lime rarely moves upward in the soil but on the other hand, tends to be removed quite rapidly thru leaching in the drainage water. The presence of lime in the subsoil does not mean, therefore, that young plants will not need lime applications on the surface. For the best early growth of legumes, such as clover and alfalfa, on the upland soils of the county practically all of the types should be tested for acidity and, if the surface soil is acid, lime should be applied.

The figures given in the tables showing the analyses of the soils of the county indicate roughly the lime needs of the various soil types. The results should be considered indicative only, however, inasmuch as soils vary widely in acidity and lime requirement and even different soils of the same type may show a different acidity. It is necessary therefore that the soil in any field be tested for lime needs before the material is employed and then the proper amount of lime may be used to secure the best results. Farmers may test their own soils for lime needs but it will usually be more satisfactory for them to send a small sample to the Soils Section of the Iowa Agricultural Experiment Station where it will be tested free of charge and recommendations made regarding treatment.

The greenhouse and field experiments which have been described earlier in this report have shown some rather striking crop increases from the applications of lime which have been made. Farm experiences with lime have also indicated the beneficial effects on crop yields from the application of this material to acid soils. It is quite evident, therefore, from tests and from experiences that the use of lime on the acid soils in Hardin county will lead to very profitable effects. Further information regarding the use of lime on soils, losses by leaching and other points connected with liming are given in Extension Bulletin No. 105, of the Iowa Agricultural Experiment Station. A list of companies prepared to furnish this material is also given in this bulletin.

MANURING

The soils of Hardin county are not strikingly deficient in organic matter as is indicated by their generally dark color. However, there is no large content of organic matter in the upland types except in the Clyde silty clay loam. In several instances the supply of organic matter is rather low. It is very necessary that organic matter be added to all of the soils in the county at regular intervals in order to keep up the supply. On those types which are rather low in this constituent, the additions of fertilizing materials supplying organic matter are particularly necessary.

Farm manure is the most important natural fertilizer which can be employed on the farm and it plays a large part in increasing and maintaining the supply of organic matter in soils. It brings about large crop increases not only on those soils which are light in color and sandy in texture and quite evidently deficient in organic matter but also on heavier soils darker in color and apparently fairly well supplied with organic matter. Larger applications may often be made to light textured soils but small applications are of value even on the heavier types.

The Carrington, Clarion and Tama soils in Hardin county, the most extensive upland types, are not particularly low in organic matter but farm manure proves distinctly beneficial on these soils. Small applications prove of value on the Webster types and other soils in the county respond similarly to the use of manure.

The usual application of manure to soils is about 8 to 10 tons per acre once in a four year rotation. Larger applications than this are rarely desirable except on very light soils or where truck crops are to be grown. On average soils, for general farm crops, the largest increases per ton of manure are secured with 8 to 10 tons.

Green manuring is an important farm practice. It is absolutely necessary on grain farms where farm manure is not produced. It is also necessary on many livestock farms in order to supplement the manure produced which is often inadequate to supply all of the soils. It is generally much more desirable to use legumes for green manuring because they not only supply organic matter but when they are well inoculated they take nitrogen from the atmosphere and may increase the nitrogen in the soil when they are turned under as green manures.

There are many cases in Hardin county where the use of legumes as green manures would undoubtedly be very desirable. Care should always be exercised, however, in following this practice as undesirable results may occur if conditions in the soil are not satisfactory for the best decomposition of the green material.

Crop residues should always be returned to the land because they contain much plant food and organic matter. If they are burned, as so often happens, there is an actual destruction of valuable fertilizer constituents. On the livestock farm the residues may be used for feed or bedding and may be returned to the land with the manure. On the grain farm they may be stored and allowed to partially decompose before applying or they may be applied directly to the soil.

THE USE OF COMMERCIAL FERTILIZERS

The amount of phosphorus present in the soils of Hardin county is generally quite low and it seems evident that phosphorus fertilizers will be needed on the soils of this county in the very near future, even if they are not of large value at the present time. The greenhouse and field experiments on the soils of the county confirm the indications from the analyses in that they show that phosphorus fertilizers may be of considerable value.

In the experiments reported, comparisons have been made of the value of rock phosphate and acid phosphate, the two most common phosphorus fertilizers. Acid phosphate provides the element in an immediately available form, while rock phosphate has a low rate of availability. Acid phosphate is more expensive but is applied in much smaller amounts. Applications of this material are made annually and usually at the rate of 150 to 200 pounds per acre. Rock phosphate, on the other hand, is applied at the rate of one ton per acre once in a four-year rotation. To determine the relative value of the two materials therefore tests must be carried on over at least one four-year rotation and the total cost of the application of the two materials must be compared with the value of the crop increase secured.

While the acid phosphate seems to be generally much better than the rock phosphate in the field experiments on the Carrington loam at Eldora, definite conclusions regarding the relative value of the two materials for the soils of the county should not be drawn. It is urged that farmers test these two phosphate fertilizers on their own soils and thus determine for their own conditions which material will be the most valuable. Simple tests may be carried out quite readily on any farm and directions which may be followed in carrying out such tests are given in Circular 82 of the Iowa Agricultural Experiment Station.

The nitrogen content of many of the soils of Hardin county is not particularly high and it seems quite evident that nitrogen must be applied to many of these soils. In some cases the type is fairly well supplied but only in the case of the Clyde silty clay loam is there any extremely large amount. In all cases, however, applications of some material supplying nitrogen must be made regularly to all of the soils of the county if the supply is to be kept up.

Farm manure is an important nitrogenous fertilizer in that it supplies a large amount of nitrogen. On livestock farms, manure, when properly preserved and applied to the soil, will aid greatly in maintaining the nitrogen supply. It will not, however, keep up the supply of nitrogen because sufficiently large amounts of manure are not available for use. On the grain farm some other nitrogenous fertilizer must be employed, and in cases where it is necessary to increase the nitrogen content some other material than farm manure is desirable.

Leguminous green manures are the cheapest and best nitrogenous fertilizers which can be employed. When a legume is inoculated, as it should be, it takes a large part of its nitrogen from the air and, when the crop is turned under in the soil as a green manure, there is a corresponding increase in the nitrogen content in the soil. There are undoubtedly many cases in Hardin county where the turning under of legumes as green manures would be profitable.

Crop residues when properly used also supply some nitrogen to the land and hence these materials should be considered as very desirable supplements to the use of farm manure and leguminous green manures.

It seems hardly possible that commercial nitrogenous fertilizers will be needed on the soils of Hardin county inasmuch as the nitrogen supply may be increased and maintained by the proper use of leguminous green manures, farm manure and crop residues. Perhaps small amounts of nitrates as top dressings might be very desirable, but for general farm crops it seems now that the natural materials, like legumes, would prove cheaper and most satisfactory.

The total amount of potassium present in the soils of Hardin county is large and it seems improbable that potassium fertilizers will prove necessary on these soils. There is enough potassium to keep crops supplied for many years if it is changed into an available form as rapidly as it should be. Potassium fertilizers cannot be recommended, therefore, for general use in the county, and only when applied in small amounts as top dressings, does it seem possible that they might prove of profit.

Complete commercial fertilizers contain phosphorus, nitrogen and potassium and hence it would seem that they might prove of considerable value on many soils. As a matter of fact, however, nitrogen can be supplied more cheaply by the use of legumes as green manures. Potassium is not likely to be deficient and

hence the chief value of the complete commercial fertilizer lies in the phosphorus content. If this is true, then acid phosphate should prove more desirable and more economic because it supplies phosphorus and is somewhat cheaper. The experimental work which has been reported earlier has indicated that practically as large effects are secured from the use of acid phosphate as from the application of a complete fertilizer. Hence, the latter materials cannot be recommended for general use in Hardin county at the present time for general farm crops. For truck and garden crops certain brands of complete commercial fertilizers are of considerable value and may frequently be used with profit.

DRAINAGE

Hardin county is rather poorly drained naturally, possessing a rather restricted drainage system in the entire area west of the Iowa river. Particularly in the northwestern and southwestern portions of the county, the natural drainage system is inadequate. An examination of the map given earlier in this report will indicate the character of the drainage system of the county. East of the Iowa river drainage is usually good, but in large areas west of the river, tiling is necessary if the soil is to be properly drained. The need of tiling is particularly evidenced in the areas of the Webster soils, flat, level uplands with heavy, rather impervious subsoils. Areas in the Carrington loam are also poorly drained and numerous of the terraces and bottomland soils are in need of drainage before they can be made satisfactorily productive. When a soil is too wet, good crop yields cannot be secured and the first treatment needed is tiling.

Many areas in Hardin county have been made more productive thru the proper use of tile and many areas still remain where drainage is not yet sufficient to make the soils as highly productive as they might be. Tiling may be an expensive operation, but the results secured warrant the outlay. Farmers in Hardin county should see that their land is adequately drained if they wish to get the best returns. No other treatments will prove of value on land which is wet and fertilizers may be wasted if they are applied to poorly drained areas. Much data is available to show the benefits from tiling. In many cases it means the difference between crop failure and very satisfactory yields.

THE ROTATION OF CROPS

It has become a rather generally accepted fact that the fertility of soils can be kept up much more readily if a crop rotation is practiced. The continuous growing of any one crop has been found to reduce fertility quite rapidly. Sometimes the large value of a particular crop has induced farmers to grow that crop year after year on the same land. Very soon, however, they have noted decreases in crop yields and eventually the crops became unprofitable. When a rotation is practiced the yields do not decrease so rapidly and even if the various individual crops included in the rotation are of somewhat less money value, the total value of all the crops grown over a period of years will be much greater where a rotation is practiced. Furthermore, for permanent fertility the rotation of crops is absolutely essential.

No particular rotation experiments have been carried out in Hardin county but there are numerous rotations which are being followed successfully and there

are many which are entirely satisfactory for average farm conditions. No one rotation can be recommended, and indeed almost any rotation will prove of value provided it contains a legume crop and the money crop. The following examples of rotations which are in common use thruout the state may serve as a basis upon which rotations suitable for Hardin county may be worked out.

1. SIX-YEAR ROTATION

First year —Corn.
Second year—Corn.
Third year —Wheat or oats (with clover, or clover and grass).
Fourth year—Clover, or clover and grass.
Fifth year —Wheat (with clover), or grass and clover.
Sixth year —Clover, or clover and grass.

This rotation may be reduced to a five-year rotation by cutting out either the second or sixth year and to a four-year rotation by omitting the fifth and sixth years.

2. FOUR OR FIVE-YEAR ROTATION

First year —Corn.
Second year—Corn.
Third year —Wheat or oats (with clover or with clover and timothy).
Fourth year—Clover (if timothy was seeded with the clover the preceding year, the rotation may be extended to five years. The last crop will consist principally of timothy.)

3. FOUR-YEAR ROTATION WITH ALFALFA

First year —Corn.
Second year—Oats.
Third year —Clover.
Fourth year—Wheat.
Fifth year —Alfalfa. (The crop may remain on the land five years. This field should then be used for the four-year rotation outlined above and the alfalfa shifted to one of the fields which previously was in the four-year system.)

4. FOUR-YEAR ROTATIONS

First year —Wheat (with clover).
Second year—Corn.
Third year —Oats (with clover).
Fourth year—Clover.

First year —Corn.
Second year—Wheat or oats (with clover).
Third year —Clover.
Fourth year—Wheat (with clover).

First year —Wheat (with clover).
Second year—Clover.
Third year —Corn.
Fourth year—Oats (with clover).

5. THREE-YEAR ROTATIONS

First year —Corn.
Second year—Oats or wheat (with clover seeded in the grain).
Third year —Clover. (In grain farming, only the grain and clover seed should be sold; most of the crop residues such as corn stover and straw should be plowed under. The clover may be clipped and left on the land to be returned to the soil and only the seed taken from the second crop.)

First year —Corn.
Second year—Oats or wheat (with clover).
Third year —Clover.

First year —Wheat (with clover).
Second year—Corn.
Third year —Cowpeas or soybeans.

THE PREVENTION OF EROSION

Erosion is the carrying away of soil thru the free movement of water over the surface of the land. If all the rain falling on the ground were absorbed, erosion could not occur, hence it is evident that the amount and distribution of rainfall, the character of the soil, the topography or the "lay of the land," and the cropping of the soil are the factors which determine the occurrence of this injurious action.

There are two types of erosion, sheet washing and gullying. The former may occur over a rather large area and the surface soil may be removed to such a large extent that the subsoil may be exposed and crop growth prevented. Gullying is more striking in appearance but it is less harmful and it is usually more easily controlled. If, however, a rapidly widening gully is allowed to grow unchecked an entire field may soon be made useless for farming purposes.

Erosion occurs to a large extent in Hardin county in the steep phase of the Carrington loam, in the steep phase Lindley loam, and in the Clinton silt loam. It also is found in some areas of the typical Carrington loam, the Clarion loam, the typical Lindley loam, the Fayette silt loam and sometimes in the other types of the Carrington series. Serious washing frequently occurs and gullying is rather common and where these effects of erosion are noted some means of prevention or control of this destructive action should be adopted.

The means which may be employed to control or prevent erosion in Iowa may be considered under five headings as applicable to "dead furrows", to small gullies, to large gullies, to bottoms and to hillside erosion.

EROSION DUE TO DEAD FURROWS

Dead furrows or back furrows, when running with the slope or at a considerable angle with it, frequently result in the formation of gullies.

"Plowing In."—It is quite customary to "plow in" the small gullies that result from these dead furrows and in level areas this process may be quite effective. In the more rolling areas, however, it is best to supplement the "plowing in" with a series of "staked in" dams or earth dams.

"Staking in".—The method of "staking in" is better as it requires less work and there is less danger of washing out. The process consists in driving in several series of stakes across the gully and up the entire hillside at intervals of from 15 to 50 yards, according to the slope. The stakes in each series should be placed three or four inches apart. It is then usually advisable to weave some brush about the stakes, allowing the tops of the brush to point upstream. Additional brush may also be placed above the stakes, with the tops pointing upstream, permitting the water to filter thru, but holding the fine soil.

Earth Dams.—Earth dams consist of mounds of soil placed at intervals along the slope. There are some objections to the use of earth dams, but in many cases they may be quite effective in preventing erosion in "dead furrows."

SMALL GULLIES

Gullies result from the enlargement of surface drainageways and they may occur in cultivated land, on steep hillsides in grass or other vegetation, in the

bottomlands, or at any place where water runs over the surface of the land. Small gullies may be filled in a number of ways but it is not practicable to fill them by dumping soil into them; that takes much work and is not lasting.

Checking Overfalls.—The formation of small gullies or ditches is practically always the result of overfalls. An easy method of checking the overfalls is to put in an obstruction of straw and brush and stake down with a post. One or more posts should be set firmly in the ground in the bottom of the gully. Brush is intertwined between the posts, straw is well tramped down behind them and the straw and brush are held in place by cross pieces nailed to the posts.

"Staking in".—The simplest method of controlling small or moderate sized gullies and the one that gives the most general satisfaction is the staking in operation recommended for the control of dead furrow gullies.

The Straw Dam.—A simple method of preventing erosion in small gullies is to fill them with straw. This may be done at threshing time with some saving of time and labor. The straw is usually piled near the lower part of the gully, but if the gully is rather long or branching, it should be placed near the middle or below the junction of the branches or more than one dam should be used.

The Earth Dam.—The use of an earth dam or mound of earth across a gully may be a satisfactory method of controlling erosion under some conditions. In general it may be said that when not provided with a suitable outlet under the dam for surplus water the earth dam cannot be recommended. When such an outlet is provided the dam is called a "Christopher" or "Dickey" dam.

The "Christopher" or "Dickey" Dam.—This modification of the earth dam consists merely in laying a line of tile down the gully and beneath the dam, an elbow or a "T", being inserted in the tile just above the dam. This "T", called the surface inlet, usually extends two or three feet above the bottom of the gully. A large sized tile should be used in order to provide for flood waters and the dam should be provided with a cement or board spillway or runoff to prevent any cutting back by the water flowing from the tile. The earth dam should be made somewhat higher and wider than the gully and higher in the center than at the sides to reduce the danger of washing. It is advisable to grow some crop upon it, such as sorghum, or even oats or rye, and later seed it to grass.

The Adams Dam.—This dam is practically the same as the Christopher or Dickey Dam. In fact the principle of construction is identical. In some sections the name "Adams dam" has been applied and hence it is mentioned separately.

The Stone or Rubble Dam.—Where stones abound they are frequently used in constructing dams for the control of erosion.

The Rubbish Dam.—The use of rubbish in controlling erosion is a method sometimes followed and a great variety of materials may be employed. The results are in the main rather unsatisfactory and it is a very unsightly method.

The Woven Wire Dam.—The use of woven-wire, especially in connection with brush or rubbish, has sometimes proven satisfactory for the prevention of erosion in small gullies.

Sod Strips.—The use of narrow strips of sod along natural surface drainageways may often prevent these channels from washing into gullies, as the sod

serves to hold the soil in place. Bluegrass is the best crop to use for the sod, but timothy, redtop, clover or alfalfa may serve quite as well and for quick results sorghum may be employed if it is planted thickly.

The Concrete Dam.—One of the more effective means of controlling erosion is by the concrete dam, provided the Dickey system is used in connection with it. They are, however, rather expensive. Owing to their high cost and the difficulty involved in securing a correct design and construction, such dams cannot be considered as adapted to general use on the farm.

Drainage.—The ready removal of excess water may be accomplished by a system of tile drainage properly installed. This removal of water to a depth of the tile increases the water absorbing power of the soil, and thus decreases the tendency toward erosion.

LARGE GULLIES

The erosion in large gullies which are often called ravines may in general be controlled by the same methods as for small gullies. The Dickey dam is the only method that can be recommended for controlling and filling large gullies and it seems to be giving very satisfactory results at the present time.

BOTTOMLANDS

Erosion frequently occurs in bottomlands and especially where such lowlying areas are crossed by small streams the land may be very badly cut up and rendered almost entirely valueless for farming purposes.

Straightening and Tiling.—The straightening of the larger streams in bottomland areas may be accomplished by any community and while the cost is considerable, large areas of land may thus be reclaimed.

Trees.—Erosion is sometimes controlled by rows of such trees as willows which extend up the drainage channels. While the method has some good features it is not generally desirable.

HILLSIDE EROSION

Hillside erosion may be controlled by certain methods of soil treatment which are of value, not only in preventing the injurious washing of soils, but in aiding materially in securing satisfactory crop growth.

Use of Organic Matter.—Organic matter or humus is the most effective means of increasing the absorbing power of the soil and hence it proves very effective in preventing erosion. Farm manure may be used for this purpose or green manures may be employed if farm manure is not available in sufficient amounts. Crop residues such as straw and corn stalks may also be turned under in soils to increase their organic matter content.

Growing Crops.—The growing of crops, such as alfalfa, that remain on the land continuously for a period of two or more years is often advisable on steep hillsides. Alsike clover, sweet clover, timothy and red top are also quite desirable for use in such locations.

Contour Discing.—Discing around a hill instead of up and down the slope or at an angle to it is frequently very effective in preventing erosion. This practice is called "contour discing" and it has proven quite satisfactory in many cases in Iowa.

Sod Strips.—The use of narrow strips of sod is very desirable for preventing hillside erosion as well as for the preventing of gully formation. The sod protects the field from the flow of water during rains and prevents the washing away of the surface soil.

Deep Plowing.—Deep plowing increases the absorptive power of the soil and hence decreases erosion. It is especially advantageous if it is done in the fall as the soil is then put in condition to absorb and hold the largest possible amount of the late fall and early spring rains.

INDIVIDUAL SOIL TYPES IN HARDIN COUNTY*

There are 25 soil types in Hardin county and these with the areas of steep phase Carrington loam, steep phase Lindley loam and peat and muck make a total of 28 separate soil areas in the county. They are divided into four groups on the basis of their origin and location, known as drift soils, loess soils, terrace soils and swamp and bottomland soils.

DRIFT SOILS

There are 10 drift soil types in the county and with the steep phase of the Carrington and Lindley loams, 12 drift areas. The soils are classified in the Carrington, Clarion, Webster, Lindley and Clyde series. Together they cover **73.9 percent of the total area of the county.**

CARRINGTON LOAM (1)

The Carrington loam is the most extensive individual soil type in the county. With the steep phase which is very small in area it covers 35.2 percent of the county. It is extensively developed on the more rolling uplands in all parts of the county except east of the Iowa river and in the southeast corner where the uplands are covered with loessial material. The largest development of the type is found in the central part of the county. It is found associated with the other upland types, being spotted with numerous small areas of the Webster soils, Clarion loam and some peat and muck. There are no extensive individual areas of the type as everywhere the Webster soils occur along all of the intermittent drainage lines, bottomland types are found adjacent to it along the rivers and the type grades into the Carrington and Clarion soils on the more rolling areas.

The surface soil of the Carrington loam is a dark brown to black loam, averaging about 14 inches in depth. It is mellow and friable and contains varying amounts of coarse sand and some gravel. The subsoil is a yellowish-brown silty clay to clay, becoming heavier in texture and lighter in color at the lower depths. Rusty brown iron stains are found in the lower part of the three foot section. Below that point glacial till occurs, pale yellow to mottled yellowish-gray silty

*The description of individual soil types given in this section of the report very closely follow those in the Bureau of Soils report.

clay to clay. Some variations occur in the soil in different areas. Sometimes there is a sandier coarser surface layer, lighter in color and varying from 5 inches to 12 inches in thickness. The subsoil is more gritty than in the case of the typical soil. This variation is found on the steeper slopes near the streams and on the hills and ridges. In the rougher areas in the eastern part of the county just west of the river, pockets of yellowish-brown gravelly sand are found on the steeper slopes and boulders are common over the surface of the upland. In the northeastern part of the county where the surface soil changes from the drift material to the loess the change in texture is quite gradual and considerable silt is sometimes found in the surface soil. The occurrence of any large quantity of silt is recognized by the mapping of the Carrington silt loam, separating the loam from the Tama silt loam. The boundary lines in both of these cases are located rather arbitrarily. There are numerous small draws and depressions in the rougher region in the eastern part of the county thruout this type, and in these depressed areas the soil is a black silty clay loam. These are too small to be separated and shown on the map. Within the type also there are small spots of yellowish-brown clay exposed on some of the steeper slopes. The heavier surface soil in the type is found developed on the gentle slopes in more nearly level areas, while the lighter textured soil is found in the rougher more rolling locations. The drainage of the Carrington loam is usually entirely adequate, in fact in some small areas where the subsoil is more sandy and gravelly, drainage may be excessive.

About 90 percent of the soil is under cultivation, the remainder being utilized for farm houses and buildings, pastures, and similar purposes. Practically none of the type is waste land. In a few of the rougher areas along streams there are patches of trees, otherwise the type is all in cultivation. General farm crops are grown, corn being the most important. Average yields of this crop amount to 45 bushels per acre. Oats is also an important crop, yielding on the average 40 to 45 bushels. In favorable seasons much higher yields of both corn and oats are frequently secured. Some wheat is grown on this type in the county particularly in the northeastern part and average yields amount to 18 to 20 bushels per acre. The principal hay crop consists of clover and timothy which yields on the average 1¼ to 2½ tons per acre. Potatoes grow well and average about 100 bushels per acre. Some sweet corn is grown in the northeastern part of the county and sold to the canning factory at Ackley. Alfalfa, sweet clover and soybeans are grown to a minor extent in the county, but all of these crops are receiving more attention.

In general, crop yields secured on the Carrington loam are fairly satisfactory but much larger crops may be secured thru proper methods of soil treatment. In the first place, the type is acid in reaction and if the best growth of legumes is to be secured, lime must be applied. The soil should be tested regularly and lime applied as required.

There is no striking deficiency in organic matter, neither is there any especially large amount. Applications of farm manure in the usual amounts are very necessary if the supply of organic matter in the soil is to be kept up and the best crop yields are to be secured. This material also aids in keeping up the

supply of plant food in the soil. If farm manure is not available for use then leguminous green manures should be employed. The experiments reported earlier and much practical farm experience have indicated the large value of lime and manure on this soil.

There are indications from these experiments also that this soil will respond to applications of phosphorus fertilizers. Whether acid phosphate or rock phosphate should be employed cannot yet be definitely said altho the indications point to a superior value for the acid phosphate. Farmers are urged to test the two phosphates on their own soils to determine which would prove the most profitable for their particular conditions. There is every reason to believe that much if not all of this soil type will respond to applications of a phosphorus fertilizer for general farm crops. In most cases acid phosphate will probably give quite as large effects as complete commercial fertilizers, and the latter materials cannot therefore be recommended for general use. Tests of their value may, however, be made in connection with the tests of phosphates and thus conclusions regarding the relative desirability for the use of the different materials may be reached.

Some of the more rolling areas of the Carrington loam are eroded and in some of the areas methods for the prevention and control of the formation of gullies and the occurrence of sheet erosion should be adopted. In a few of the flatter areas drainage is not entirely adequate and where this occurs tile should be installed.

CARRINGTON LOAM (STEEP PHASE) (57)

The Carrington loam, steep phase, is of minor occurrence in the county, covering less than 1 percent of the total area. It occurs in narrow strips along Tipton and Honey creeks, along the upper course of the Iowa river and in small patches along the South Fork of the Iowa river. There are no extensive occurrences of the type. The largest individual area occurs along Tipton creek where it joins the river.

The surface soil is a thin layer of black to dark brown friable loam, 3 to 6 inches deep. The subsoil is a yellowish-brown or pale yellow, gritty silty clay to clay loam. Coarse sand, pebbles and boulders are found thruout the surface soil and subsoil. On the steeper hillsides, the surface soil has been very largely removed by erosion. Along the Iowa river near Iowa Falls areas are included with this type where the limestone outcrops form perpendicular walls, and where the thin surface covering is highly calcareous. These areas could not be separated out because of their small extent.

This soil is largely forested with hickory, elm, bass wood, oak, maple and other hard woods. It has little value agriculturally and practically none of it is under cultivation. It is largely used for pasture and supports a good growth of bluegrass. It is injured to a very large extent by erosion when not kept in good sod and in many areas much of the surface soil has been washed away and numerous gullies have been formed. The phase is suitable practically entirely for pasture purposes.

Fig. 7. Clarion loam topography.

CLARION LOAM (138)

The Clarion loam is the second largest soil type in the county, covering 70,912 acres or 19.5 percent of the total area. It occurs mainly in the western and north central portions of the county, being the chief upland type in Concord, Buckeye, Alden, Hardin and Ellis townships. The largest developments are found near Garden City, Radcliff, Buckeye and south of Alden. The type occurs on slopes bordering flat areas of the Carrington loam and in undulating areas on the more or less level land occurring between the natural drainage lines.

The surface soil of the Clarion loam is a dark brown to black friable loam about 12 inches in depth. The subsoil is a yellowish-brown silty clay to clay loam. The lower subsoil at a depth of 24 to 30 inches consists of light yellowish-brown or grayish-yellow silty clay to sandy clay loam mottled with gray. This subsoil layer is high in lime, containing streaks and nodules of calcareous material. Iron stains sometimes occur. Some fine sand, coarse sand, gravel and boulders occur thruout the soil section and are most abundant in the subsoil. The surface soil is somewhat variable in character, ranging in texture from a heavy loam on the lower gentle slopes to a coarse gritty loam on small knolls. Pockets of sand and gravel sometimes occur. In a considerable area south of Alden the type is very much like the Webster loam, the surface soil is black and the yellowish-brown non-calcareous layer is thin. The type very closely resembles the Carrington loam to a depth of 24 to 30 inches; below that point the subsoil is more like the Webster.

The type is all under cultivation. Corn, oats and hay are the chief crops grown. Corn averages 45 bushels per acre, oats 45 to 50 bushels and clover and timothy about 1½ tons. Alfalfa yields 3 to 3½ tons.

In favorable seasonal conditions yields of general farm crops are quite satisfactory, but, in general, considerable increases in crops may be secured thru proper soil treatment. Liberal applications of farm manure are very desirable in order to build the soil up in organic matter, supply plant food and provide the best physical conditions for the production of available plant food. If farm manure cannot be employed then some legume should be turned under as a green

manure. The type may be acid in the surface soil even tho lime is present in the subsoil. A treatment of the surface soil would be very desirable in order to secure a good initial growth of legumes. There are indications that phosphorus fertilizers may prove of considerable value on this type and tests of acid phosphate and rock phosphate on individual farms are recommended. The type may be slightly eroded in some cases in the more rolling areas and when this is true some method of prevention or control of this destructive action should be practiced. On some of the flatter areas drainage is not quite adequate and tiling out such areas is necessary in order to insure the best crop yields.

WEBSTER SILTY CLAY LOAM (107)

The Webster silty clay loam is the fourth largest soil type in the county, covering 10 percent of the total area. It occurs in all parts of the county except in the loessial region in the east. It is developed in narrow strips, in flat depressions on the broad areas between the streams, many of which were formerly ponded much of the time. Practically all of the areas of the type are small, the largest occurrence in individual areas being found three miles west of Alden and three miles south of Iowa Falls. The type occurs in association with the Carrington and Clarion soils on the uplands and along the intermittent drainage channels. In fact thruout the major portion of the upland of the county the small depressed areas are either Webster silty clay loam or Webster loam.

The surface soil of the silty clay loam is a black sticky silty clay loam to clay loam grading into a very dark brown to black clay loam at 8 to 12 inches. The subsoil at 22 to 24 inches is a light yellowish-brown or grayish clay loam to silty clay with many gray iron and yellow mottlings and small rusty brown iron stains. The subsoil is high in lime and when dry is a pale yellow color. In some areas the dark brown to black soil extends to a depth of 3 feet. Included within the type are small areas of peat and muck which were too small to separate on the map. Alkali spots occur along the margins of the peat and muck beds and along ponded areas which have recently been drained.

The type occurs usually from 2 to 6 feet below the surrounding upland and formerly the areas were all too wet for cultivation. Many of them were ponds. The type is naturally poorly drained but much of it has been made productive thru the installation of tile and drainage ditches. The latter are often necessary as the natural drainage system is not very adequate.

The soil is used largely for general farm crops and corn, oats and hay are grown. Corn yields from 35 to 70 bushels per acre, oats from 30 to 60 bushels and hay from 1 to 2 tons. This type needs principally thoro drainage for more satisfactory crop growth. Wherever drainage has not proven adequate tile should be installed. Careful plowing and cultivation of the soil is necessary as it may clod and pack if plowed and cultivated when too wet. In very dry weather surface cracking often occurs in spite of a good mulch. In wet seasons small grain crops are apt to lodge but in favorable seasons crop yields are excellent.

Small applications of farm manure on newly drained areas may be desirable but large amounts should not be used preceding the growth of small grains. The

Fig. 8. Webster loam west of Alden.

type is not apt to be acid but if such is the case lime may prove of value for securing good early growth of legumes. The addition of phosphorus fertilizers may prove of considerable value and tests of rock phosphate and acid phosphate on this soil are recommended.

WEBSTER LOAM (55)

The Webster loam is a minor type in the county, covering 3.1 percent of the total area. It occurs in the uplands in the western part of the county in association with the Clarion and Carrington soils and with the Webster silty clay loam. The largest occurrences of the type are found two miles northwest of Buckeye and in the northwest corner of the county. Many of the areas of the type are very small and occur with the Webster silty clay loam in depressed areas in the upland. The type is found on the more level to depressed uplands usually lying, however, somewhat higher than the silty clay loam of the same series.

The surface soil of the Webster loam is a black heavy loam 12 to 16 inches in depth, grading at that point into a dark brown to black silty clay loam, 2 to 4 inches in thickness. The subsoil is a grayish-brown or yellowish-brown silty clay loam, mottled with gray and yellowish-brown. Much coarse sand and gravel occur thruout the soil section, larger amounts being present in the subsoil. The lower layers are highly calcareous and contain many lime nodules. Within the type there are included narrow strips of the silty clay loam which were too small to be shown separately on the map.

In some areas of the type there are scattered mound-like swells 4 to 15 feet in diameter in which the soil is a coarse loam to gravelly loam underlaid by a coarse gritty clay subsoil, changing at 30 to 36 inches in many places to a coarse grayish clayey sand. The natural drainage of the Webster loam is poor but most of the areas have been tiled and are now fairly adequately drained.

The type is practically all used for cultivated crops, only a few small areas being in native grasses. Corn, oats and hay are the chief crops grown, the yields being very much the same as on the Webster silty clay loam. Crops, how-

ever, are not so apt to be injured in wet seasons on this type as on the heavier soil. Small applications of farm manure would prove of value on this soil by a stimulation of the processes bringing about available plant food production and also because of the improvement in the physical condition of the soil. Large applications should not be made preceding the growing of a small grain crop. The application of a phosphate fertilizer may be very desirable on this soil and tests of acid phosphate and rock phosphate are recommended. Adequate drainage of the type should first be secured and then good crop yields may be obtained. Increases may be secured by following various methods of soil treatment as suggested.

CARRINGTON SILT LOAM (83)

The Carrington silt loam is a minor type in the county, covering 1.4 percent of the total area. It occurs mainly in the northeastern part of the county in Aetna and Clay townships, separating the Clarion soils on the drift upland from the Tama soils to the east on the loessial upland. The largest area is south of Abbott Crossing. Other areas are found southwest of Ackley near Steamboat Rock and south of New Providence. Scattered areas occur along the streams east of the Iowa river and in small areas in the upland.

The surface soil of the Carrington silt loam to a depth of 14 inches is a dark brown to black friable mellow silt loam, faintly mottled with gray and brown. The subsoil is a yellowish-brown silty clay loam to clay loam, highly mottled with yellow and gray. The lower subsoil is somewhat heavier than the upper subsoil. Fine and coarse sand and some gravel occur in the subsoil. The surface soil is somewhat variable, consisting mainly, however, of loessial silt with some mixture of fine drift material. The boundary lines between this type and the Carrington loam and Tama silt loam are frequently rather arbitrarily established as there is a gradual change from one soil to the other. In the areas in the eastern part of the county where the type occurs adjacent to the streams there has been much erosion and the surface soil is more or less a mixture of loess with underlying drift. The soil is well drained and on the steeper slopes excessively drained.

All of the soil is under cultivation and crop yields are very much the same as on the Tama silt loam with which the soil is closely associated. Crop yields are fairly satisfactory but increases may be secured thru the proper soil treatment. The type is acid and in need of lime. It will respond to applications of farm manure and the addition of a phosphate fertilizer would probably prove of value. Tests have indicated a large profit from the use of farm manure, lime and phosphorus. Farmers are urged to test the relative value of rock phosphate and acid phosphate as it is not yet possible to choose between the two materials for the particular conditions pertaining to this soil.

LINDLEY LOAM (65)

The Lindley loam is a minor type in the county. Together with the steep phase which is smaller in area it covers 1.3 percent of the county. It occurs mainly in narrow strips on the steep slopes of the Iowa river, separating the upland from the bottoms. There are a few narrow areas along Honey creek.

The largest development of the type is found north of Steamboat Rock and in the vicinity of Eldora to the northeast and southeast of the city.

The surface soil of the Lindley loam is a grayish-brown or brown loam extending to a depth of 8 inches. When dry the soil appears a light grayish-brown or gray. The subsoil is a yellowish-brown or reddish-brown clay or silty clay loam. In the areas from Steamboat Rock to Eldora the subsoil is mainly a reddish-brown while in the areas south of Eldora the subsoil is light yellowish-brown mottled with yellow and gray. On the steeper slopes there are many exposures of yellowish or reddish gritty clay loam, the surface soil having been very largely removed by erosion. Spots of very fine sandy loam and fine sandy loam are included in the type owing to their small extent. Rock fragments occur thruout the soil and boulders of varying sizes are found both on the surface and thru the soil section. On the upper slopes the surface soil is often much modified by the silt washing in from the higher uplands.

Originally the type was covered with a dense growth of hickory, white oak, elm, ash, post oak and other hard wood trees and shrubs but the forest growth is now rather thin. About five percent of the type is now under cultivation, cultivated areas being found on the lower parts of the slopes adjacent to the bottoms. The type is used largely for pasture and it is undoubtedly better adapted for grazing purposes. It is very readily eroded and unless kept in sod, gully formation is extensive. Only on the areas at the base of the slopes would the growth of general farm crops be desirable. In these areas the soil would respond to applications of farm manure, lime and probably phosphorus. On the major portion of the areas attention should be directed chiefly to the maintenance of a good bluegrass sod.

Fig. 9. Horseshoe bend in the Iowa river near Eldora. Lindley loam in the foreground and Wabash loam in the bottoms.

Fig. 10. Narrow valley of the Iowa river near Steamboat Rock. Lindley very fine sandy loam on the slopes and Wabash loam in the bottoms.

LINDLEY LOAM (STEEP PHASE) (187)

The steep phase Lindley loam is somewhat smaller in area than the typical soil, covering 1,984 acres. It occurs along the Iowa river, chiefly in narrow areas adjacent to the bottoms frequently separating the Lindley very fine sandy loam from the bottoms. The main occurrence of the type is from Steamboat Rock north along the river.

The surface soil is a grayish or yellowish-brown loam 4 to 8 inches deep. The underlying subsoil consists of a gritty compact yellowish-brown clay loam. In some places perpendicular limestone ledges are exposed at the lower ends of the deep valleys of the tributary streams where they join the river. The phase occurs on slopes which are steep to precipitous, rising 100 to 175 feet above the river channel. The surface soil is very readily washed away from these steep slopes and erosion is very active unless the areas are well protected by forest growth and a good sod.

The type is generally forested with a dense growth of soft maple, red oak, white oak, prickly ash, white ash, bass wood, elm, black maple, red cedar, white pine, white birch, hackberry and cherry birch. The type is too steep for profitable agricultural utilization. It supplies only poor pasture and the maintenance of a stand of bluegrass is very difficult.

LINDLEY VERY FINE SANDY LOAM (137)

The Lindley very fine sandy loam is a minor type in the county, covering 1.1 percent of the total area. It is found on the rolling uplands joining the steep hillsides leading down to the bottoms of the Iowa river north from Steamboat Rock to Eagle City, the largest areas occurring just to the north and west. It

extends back from the bluffs from one-eighth of a mile to one and one-half miles gradually merging into the Carrington loam of the more gently rolling uplands. A few small areas are also found along the lower course of Honey creek and the South Fork of the Iowa river.

The surface soil of the Lindley very fine sandy loam is a friable almost floury, grayish-brown very fine sandy loam, faintly mottled with gray and yellow, and extending to a depth of 18 inches. The subsoil from 18 to 36 inches is a brown silty clay loam to clay loam with pronounced yellowish and gray mottlings. Some rock particles and fine gravel occur thruout the subsoil. The surface soil is somewhat variable in texture and in some spots is a silt loam, whitish gray in color. These usually appear in depressions. In some small areas there is much coarse sand and gravel. An area one and one-half miles southwest of Abbott in section five of Clay township consisting mainly of a coarse-textured Lindley loam has been included with the type because of its small extent. Other small areas containing coarse sand, fine rock and gravel have also been included. In these areas the surface soil is a grayish-brown to yellowish clay loam and the subsoil is a gritty yellowish-brown silty clay loam to clay loam, mottled with gray and yellow. This soil was originally heavily forested but the tree growth is at present rather thinly scattered over the areas.

Probably about one-third of the type is in cultivation. Crop yields are much the same as on the Clinton silt loam. Drainage is apt to be excessive, erosion occurs quite readily and gully formation is rather common. When cultivated this soil is particularly in need of organic matter and should receive liberal applications of farm manure and leguminous crops should be turned under as green manures. It is acid and in need of lime and phosphorus fertilizers would undoubtedly prove of value. Particular care should be taken to protect the soil from erosion if satisfactory crop growth is to be secured.

CLYDE SILTY CLAY LOAM (85)

The Clyde silty clay loam is a minor type in the county, covering 0.9 percent of the total area. It is confined to the northeast corner of the county, south of Ackley and to a few small areas along the southern boundary of the county directly south of New Providence. It occurs at the heads of small drainageways or along gentle slopes. A typical development is directly south of Ackley where the type separates the Carrington silt loam from the Tama silt loam, occurring also along the intermittent drainage lines thru the Tama silt loam and the Carrington silt loam on the south in numerous small areas.

The surface soil of the Clyde silty clay loam is a black silty clay loam grading at about 14 inches into a stiff plastic heavy silty clay or clay loam. The subsoil is a grayish-brown or drab clay loam, mottled with gray, yellow or brown. Spots of coarse material may occur in the subsoil and boulders are sometimes found scattered over the surface. Small patches of muck are found in some parts of the type. Occasionally the lower subsoil shows a lime content, but ordinarily the soil is non-calcareous thruout the three foot section. Drainage is poor and tiling is the first treatment needed to make the soil satisfactorily productive.

About 60 percent of the type has been tiled and is used for general farm crops. The untreated areas are utilized for pasture. The yields of general farm crops

are quite satisfactory when the land is thoroly drained. Larger crops may be secured, however, on this soil thru the proper use of farm manure, the application of lime as needed, and the use of a phosphate fertilizer.

CARRINGTON VERY FINE SANDY LOAM (4)

The Carrington very fine sandy loam is a minor type in the county, covering 0.9 percent of the total area. It is most extensively developed south of Eldora, on the slopes and ridges adjacent to the broad terraces on the east side of the South Fork of the Iowa river, and on the east bank of the Iowa river. Numerous areas occur all the way from Eldora to the Marshall county line along the river. Other areas are found three miles north of Alden and two and one-half miles south of Union along Honey creek.

The surface soil of the type is a dark brown fine sandy loam extending to a depth of about 10 inches at which point it grades into a lighter yellowish-brown fine sandy loam mottled with yellow and gray. When dry the surface soil appears grayish or light grayish in color. Considerable coarse sand occurs thruout the soil section. The type is not calcareous except occasionally at very low depths in the subsoil. In some areas along the lower course of the Iowa river, the surface soil varies to a loamy fine sand or fine sand in texture. In these areas there is considerable shifting and drifting of the soil from the action of winds.

Most of the type is in cultivation and ordinary field crops are grown. Average yields are somewhat lower than those secured on the Tama silt loam and are especially low in dry seasons as the soil is apt to be droughty. A few hill slopes have scattered areas of hard wood trees and hazel brush. This soil is particularly in need of organic matter in order to make it more productive. Liberal applications of farm manure should be made and leguminous crops should be used as green manures. The soil is acid and in need of lime for the best growth of legumes. It would undoubtedly respond to the application of phosphorus fertilizers.

CARRINGTON SANDY LOAM (3)

The Carrington sandy loam is a minor type in the county, covering 0.5 percent of the total area. It occurs mainly in the northwestern and southern parts of the county in small individual areas, ranging from 20 to 80 acres. It is found on the higher hills within or adjacent to the Carrington loam areas. The largest area of the type is found adjacent to and west of Iowa Falls. Small areas occur in several parts of the county, some separating the uplands from the bottoms.

The surface soil of the Carrington sandy loam is a brown to dark brown sandy loam grading at about 10 inches into a yellowish-brown sandy loam subsoil. The subsoil contains, usually, a high amount of clay and silt. Below the three foot section the subsoil is a pale yellow sandy loam and sandy clay loam and in some places this material occurs within the three foot section along steeper eroded slopes and along hill crests. Wide variations occur in this soil on the gentler slopes. The soil is more loamy, a little blacker in color, contains less coarse sand and glacial till than is the case on the higher lying areas. Within the type there are included areas which are very gravelly, occurring on the morainic ridges

scattered over the southwestern part of the county but mainly in Grant township. In these areas the crests and ridges consist of a coarse gravelly loam containing boulders of varying sizes. The layers of gravel and boulders often extend back into the hills and frequently make up a large part of the bulk. Land where such stoney and gravelly areas occur is very droughty and of little value agriculturally. Sometimes a sandy loam covers the gravelly deposits and where this is the case the soil may be used agriculturally. Yields, however, are apt to be low owing to drought.

Most of the soil in this type is farmed with the Carrington loam. On some of the hilly areas along the bottoms on the Iowa river the soil is used for permanent pastures. There are scattered clumps of hard wood trees and hazel thickets. Except for the gravelly areas mentioned above there is very little waste land in the type. General farm crops are grown and yields in favorable seasons are not much lower than on the Carrington loam. In dry seasons, however, the yields may be very unsatisfactory.

This soil is particularly in need of organic matter and it should receive liberal applications of farm manure and leguminous crops should be turned under as green manures. It is acid and in need of lime and it probably would respond to phosphorus fertilizers. The chief need of the type is for an abundance of organic matter to prevent its rapid drying out and the injury to crops which occurs in dry seasons.

LOESS SOILS

There are four loess types in the county classed in the Tama, Clinton, Fayette and Muscatine series. Together they cover 15.2 percent of the total area of the county.

TAMA SILT LOAM (120)

The Tama silt loam is the largest of the loess soils and it is the third largest type in the county, covering 13.2 percent of the total area. It is found only in the eastern and southeastern parts, being the main upland type in that part of the county east of the Iowa river and in the southeastern townships. The more

Fig. 11. Tama silt loam near Eldora.

extensive development of the soil is found in Union and Providence townships.

The surface soil of the Tama silt loam is a friable mellow dark brown silt loam to a depth of 10 to 15 inches. Below this point there is a layer of dark brown clay loam to a depth of 18 inches. The subsoil is a yellowish-brown friable but compact clay loam slightly mottled with gray. In the areas extending from a point four and one-half miles northeast of Eldorado north to the county line the loessial covering is thin, ranging from 30 to 60 inches and in some places drift material from the underlying Kansan till is found at 28 to 34 inches. The material is sometimes a very fine sand with quantities of coarse sand and fine gravel. In the southern part of the county the loess from which the Tama silt loam is derived is much deeper, extending from 25 to 50 feet above the original drift deposit. In this portion of the county the slopes are more pronounced and the tributary streams have cut thru the uplands to a greater extent. In the northern part of the area the topography is more gently rolling.

The Tama silt loam is all under cultivation except for the steeper slopes which are forested with a thin growth of trees and shrubs and utilized for pasture. All of the general farm crops are grown, corn being the most important. This crop yields from 40 to 70 bushels per acre, clover and timothy make up the hay crop and yields of 1½ to 2½ tons per acre are secured. Some clover is grown alone, some clover seed is produced and there are small acreages in wheat, rye, soybeans and millet. Alfalfa is grown very successfully in some areas. Some small fruits, potatoes and truck crops are raised, chiefly, however, for home consumption. Many orchards, chiefly apple orchards, are found on the type and good yields of apples are secured.

The soil may be made more productive thru better treatments. It will respond to applications of farm manure and this material should be applied in liberal amounts. The type is acid and lime should be used for the best growth of legumes. It will also respond profitably to the application of a phosphorus fertilizer. The experimental results given earlier in this report show quite definitely the value of farm manure, lime and phosphorus on this soil. Farmers are urged to test phosphate fertilizers on their own farms and determine for their particular conditions whether rock phosphate or acid phosphate should be employed. The indications are that the acid phosphate will be the more satisfactory.

CLINTON SILT LOAM (80)

The Clinton silt loam is a minor type in the county, covering 1.2 percent of the area. It occurs along the Iowa river in numerous areas of varying size, from Steamboat Rock south to the county line. It is also developed along some of the larger tributary streams in small areas. The largest area of the type is directly south of Steamboat Rock along Pine creek, occurring adjacent to the creek bottoms and separating the Tama and Fayette soils from the bottomland. It frequently separates the more rolling loessial upland from the steep Lindley areas along the valleys.

The surface soil of the Clinton silt loam is a grayish-brown or light yellowish-brown silt loam extending to a depth of 10 to 15 inches. The subsoil is a compact, tenacious light yellowish-brown silty clay to clay loam. Gray mottling

occurs in both the surface and subsoil. Generally the surface soil has a rather high content of very fine sand. When wet the surface has a brownish appearance and the subsoil becomes very tenacious. Within this type there are included several small areas of Clinton very fine sandy loam. These could not be separated owing to their small extent. These areas are found in sections 22 and 28 of Eldora township and in sections 10, 15, 23 and 26 of Union township.

Originally the type was forested with a dense growth of hickory, elm, ash, oak and other hard wood trees. About two-thirds of the type is now under cultivation, the remainder being in forested pasture. In topography the soil is rolling to broken and drainage is good to excessive. Erosion is very apt to occur and gullies are of frequent occurrence. In the cultivated areas general farm crops are grown and yields of corn amount to 25 to 50 bushels per acre Other crops produce about the same as on the black upland types.

The soil is particularly in need of organic matter to insure better crop production and liberal amounts of farm manure should be employed. Legume crops might often be used as green manures with profit. The soil is acid and should be limed. Applications of phosphate fertilizers are very desirable. The experimental data given earlier in this report and other results secured on this soil type elsewhere indicate quite definitely the value of applying phosphate fertilizers. Where proper amounts of organic matter are used, the soil is protected from erosion to a very large extent. Most of the areas are suitable for the growth of cultivated crops and only in the very steep locations is it necessary to allow them to remain in pasture.

FAYETTE SILT LOAM (163)

The Fayette silt loam is a minor type in the county, covering 0.4 percent of the total area. It occurs only east of the Iowa river northeast and southeast of Eldora. The largest area is to the northeast of the city.

The surface soil of the Fayette silt loam is a grayish-brown smooth silt loam, 12 to 16 inches in depth. The subsoil is a compact but friable yellowish-brown heavy silt loam or silty clay loam. In places the subsoil has a grayish cast and iron stains are abundant. In some areas the surface soil contains a large amount of very fine sand but usually it is a typical silt loam. The type appears on the flat tops of the upland plain between the Tama silt loam and the Clinton silt loam. The topography is level to flat and drainage is rather slow.

The type was originally forested but it has all been cleared and is now in cultivation. General farm crops are grown and yields are much the same as on the Tama silt loam. The needs of the type and its response to treatment are likewise very much the same as on the Tama silt loam. Applications of farm manure are of value and green manuring might very often prove profitable. Lime is necessary for the best growth of legumes and the application of a phosphorus fertilizer may often prove profitable.

MUSCATINE SILT LOAM (30)

The Muscatine silt loam is a minor type in the county, covering 0.4 percent of the total area. It occurs only in the extreme eastern part of the county from Pine creek south to Whitten. The largest areas occur in sections 1 and 2 of

Fig. 12. Purebred Holsteins belonging to the State Industrial School at Eldora, Iowa. O'Neill loam terraces.

Eldora township and around Whitten. Numerous small areas occur in association with the Tama silt loam on the more rolling upland.

The surface soil of the Muscatine silt loam is a heavy black friable silt loam extending to a depth of 10 inches, at this point passing into a dark brown to black stiff clay loam with some gray mottlings. Below 20 inches the subsoil is a grayish-brown or yellowish-brown impervious silty clay to clay, strongly mottled with gray and yellow. Iron stains are common in the lower part of the three foot section. In topography the type is flat to depressed and the natural drainage is poor.

The soil is all under cultivation and general farm crops are grown, yields being very much the same as on the Tama silt loam, provided the areas are adequately drained. This is the first treatment needed to insure good crop production. Applications of farm manure are also of value on this soil, especially when it is newly drained. It is acid and in need of lime and some experiments have indicated considerable value from the application of phosphate fertilizers.

TERRACE SOILS

There are seven terrace soils in the county classified in the O'Neill, Buckner, Waukesha, Bremer, Millsdale and Fargo series. Together they cover 4.6 percent of the total area of the county.

O'NEILL LOAM (108)

The O'Neill loam is the largest of the terrace soils but it is not an extensive type, covering only 2.2 percent of the total area. It occurs extensively along the Iowa river, the South Fork of the Iowa river and Beaver creek. Small areas are also common along Elk, Tipton and Honey creeks. The largest development of the type is found just west of Eagle City, southwest of Eldora, and northwest of Gifford.

The surface soil of the O'Neill loam is a loose friable loam to almost a sandy loam extending to a depth of about 10 inches. The texture of the surface soil

Fig. 13. High terraces near Iowa Falls. O'Neill loam and Buckner loam.

is somewhat variable as is also the depth. The upper subsoil is a yellowish-brown coarse sandy loam, mottled with yellow and brown, grading at 18 to 20 inches into a layer of yellowish-brown gravelly loam from 4 to 10 inches in thickness. Below the subsoil there is a deposit of coarse gravel varying in thickness from 5 to 25 feet and more or less gravel is found thru the surface and the subsurface soil as well as in the subsoil. Narrow strips of fine sandy loam and sandy loam, 10 to 40 feet in width, are included in this type owing to their small extent. These areas occur mainly northeast of Gifford and southeast of Union, their location being indicated by a somewhat higher position. In topography the O'Neill loam is almost level, few ridges and depressions occurring. The terraces are mostly 8 to 25 feet above the bottomland. Between Steamboat Rock and Iowa Falls the terraces lie 30 to 50 feet above the river. The drainage of the type is adequate to excessive. In those areas where the subsoil is coarser in texture the type is very droughty.

Practically all of the soil is under cultivation and corn, oats and hay are the chief crops grown. Corn yields from 25 to 50 bushels per acre. Some rye is grown. Potatoes and melons are produced in certain areas. This soil is particularly in need of organic matter in order to make it retentive of moisture. Large amounts of farm manure may be applied with profit and leguminous green manure crops should frequently be employed. These treatments will permit of the better retention of moisture and the crops will be less apt to suffer in dry seasons. The type is acid and lime should be used in order to secure the best growth of legumes. Phosphorus fertilizers would undoubtedly prove of value and tests of the value of acid phosphate on the type are strongly recommended.

BUCKNER LOAM (38)

The Buckner loam is a minor type in the county, covering 0.6 percent of the total area. It occurs in numerous areas along the entire course of the Iowa river. The largest areas are found in the vicinity of Union, and near Eagle City.

The surface soil of the Buckner loam is a moderately brown to dark brown

loam, 18 to 20 inches in depth. The subsoil is a yellowish-brown sandy loam or fine sandy loam mottled with brown or yellow. Small amounts of coarse sand and gravel are found thruout the soil section, being present in larger amounts in the lower subsoil. Pockets of coarse sand and gravel are frequently encountered. The topography of the Buckner loam is flat, with a gentle slope to the streams. Drainage is adequate except in occasional spots. Between Steamboat Rock and Iowa Falls the soil is 25 to 50 feet above the first bottoms, ordinarily it is only 10 to 15 feet above overflow.

Practically all of the type is under cultivation and general farm crops are grown. In average seasons the yields are much the same as on the upland types. Crops are sometimes injured by prolonged droughts. The soil needs applications of farm manure or the turning under of leguminous crops as green manures in order to become more satisfactorily productive. These materials will prevent to a large extent drought injury to crops. The type is acid and needs lime. Applications of phosphorus fertilizers would undoubtedly prove of large value.

WAUKESHA SILT LOAM (75)

The Waukesha silt loam is a minor type in the county, covering 0.6 percent of the total area. It occurs in numerous areas along the Iowa river from Eagle City south. Small areas are found in many other parts of the county and along many of the principal streams. Several areas occur along the South Fork of the Iowa river and some along Honey creek. The largest individual areas are located at Eldora Junction and south of Eagle City.

The surface soil of the type is a dark brown heavy silt loam extending to a depth of 20 inches. At this point it passes into a brown silty clay loam subsoil. Faint gray mottlings occur in both the surface soil and subsoil, becoming pronounced in the lower part of the three foot section. On the borders of the areas adjacent to the uplands there is some admixture of coarse sand and gravel with the silt. Considerable coarse sand and fine sand with rock fragments and gravel occur along the edges of the areas adjacent to some of the first bottoms. In section 34 of Clay township an area has been included with this type which is not typical. Here the surface soil is a grayish-brown silt loam to a depth of 15 to 18 inches. The subsoil is a very heavy and tenacious yellowish-brown silty clay to clay loam. The area is really Jackson silt loam but could not be separated owing to its small extent. Areas of Waukesha loam have also been included in the type on account of their small size. In these areas the soil is a dark brown loam and the subsoil varies from a loam to a stiff silty clay. The only very important area of this soil which is included with the typical silt loam is found north of Alden on the west side of the Iowa river. In topography the Waukesha silt loam is rather level, drainage is entirely adequate. The type is developed on terraces lying 5 to 15 feet above the first bottoms.

Practically all of the soil is under cultivation and general farm crops are grown. The yields secured are very much the same as on the Tama silt loam. The treatments which the soil needs to make it more productive are similar to those required on the Tama. Applications of farm manure prove of large value. In some cases leguminous green manures would be of value. The soil is acid and

Fig. 14. Terrace along the Iowa river west of Iowa Falls. O'Neill loam, Fargo silty clay loam and Millsdale loam.

needs lime, and the use of a phosphate fertilizer will undoubtedly prove profitable.

MILLSDALE LOAM (188)

The Millsdale loam is a minor type in the county, covering 0.5 percent of the total area. It occurs only along the Iowa river between Alden and Steamboat Rock. The largest development of the type is found in the vicinity of Iowa Falls to the west and to the southeast along the river. A rather large area occurs southeast of Eagle City.

The surface soil of the Millsdale loam is dark brown to black mellow friable loam, 14 to 16 inches in depth. The subsoil is a brown silty clay to clay loam mottled with yellowish-brown. At depths varying from 20 to 24 inches the soil rests upon limestone and outcrops of this material appear in various places. In sections 6 and 7 of Clay township there is an area included with the type which is not typical. The surface soil is a grayish to light brown and contains a large amount of silt. The edge of the terrace is a steep slope and the underlying limestone is 4 to 5 feet below the surface. In topography the type is nearly flat and usually there is an abrupt drop to the bottomlands.

Except for the area mentioned in Clay township the Millsdale loam is all in cultivation. Crop yields are quite satisfactory except in a few areas where the soil is very shallow and the limestone outcrops. Applications of farm manure would be of value on this soil and if the surface soil is acid, as frequently is the case, an application of lime would be desirable. The use of a phosphate fertilizer might also prove of value.

FARGO SILTY CLAY LOAM (109)

The Fargo silty clay loam is a minor type in the county, covering 0.3 percent of the total area. It occurs in various areas along the Iowa river, the South Fork of the Iowa river, and Beaver creek. The most extensive development of the soil is found along Beaver creek, northwest of Eldora. Most of the areas are small and relatively inextensive.

The surface soil of the Fargo silty clay loam is a sticky dark brown to black silty clay loam to clay loam, grading at 8 to 10 inches into a black tenacious clay loam to clay. At 18 to 22 inches the subsoil, consisting of a grayish-brown clay loam to clay mottled with gray, is encountered. Some yellowish-brown mottlings and brown iron stains are found in the lower subsoil. In general the subsoil is high in lime content, containing many nodules and concretions. This soil is developed on the terraces, occurring in the lower depressions at the edge of the upland slopes where they join the terraces. The natural drainage is poor. The surface is level to flat and the areas usually slope to the center and until drainage is provided water stands in the center of the areas. In some places these wet spots have led to the development of peaty and mucky areas.

The undrained areas are in pasture. The major portion of the soil has, however, been drained and general farm crops are grown with good yields. The type is naturally very productive. Drainage is the first treatment needed. Small applications of farm manure would be of value on newly drained areas. Applications of phosphate fertilizers might be desirable in some places.

BUCKNER FINE SANDY LOAM (45)

The Buckner fine sandy loam is a minor type in the county, covering 0.2 percent of the total area. Four small areas of this type occur in the county, two west of Eagle City. The other areas occur north of Eldora and south of Steamboat Rock.

The surface soil of the Buckner fine sandy loam is a light brown fine sandy loam 18 to 20 inches in depth. When dry the soil has a grayish appearance. Below 20 inches the subsoil is a yellowish-brown fine sandy loam mottled with brown and yellow. Coarse sand and gravel occur scattered thru the soil and subsoil. The surface topography of the type is rather uneven, shallow ridges and mounds occurring, due mainly to the shifting of the surface soil by the wind. Drainage is good to excessive.

General farm crops are grown on practically all of the soil and average yields of the various crops are secured, except in dry seasons when crops are very apt to be injured. The first need of the soil is for organic matter and it should receive liberal applications of farm manure. Leguminous crops as green manures would also help build up the organic matter in the soil and lessen the danger of injury from drought. The type is acid and needs lime. Undoubtedly it would respond also to an application of a phosphate fertilizer.

BREMER SILTY CLAY LOAM (43)

This is a minor type in the county, covering 0.2 percent of the total area. It occurs in depressions on the terraces along the Iowa river in the vicinity of Union. The largest area is just south of Union.

The surface soil of the Bremer silty clay loam is a black silty clay to clay loam, mottled with gray when dry, extending to a depth of 8 inches. From 8 to 18 inches the subsoil is a dark brown to black clay loam to clay, somewhat mottled with gray. The lower subsoil is a yellowish-brown clay loam to clay with many yellow and gray mottlings. Iron stains are numerous in the lower layers. Occa-

sionally there is some fine sand on the surface due to the surface wash from the higher lying soils. The Bremer silty clay loam lies above ordinary overflow but occasionally in periods of high water the type may be flooded.

With the exception of a narrow strip south of Union and a small area in section 36 of Union township the type is all in cultivation, general farm crops being grown. The soil is naturally productive when well drained. Tiling out wet areas is the first treatment needed. Small applications of farm manure are then very desirable. The soil is acid and lime should be applied. Probably a phosphate fertilizer would prove of considerable value.

SWAMP AND BOTTOMLAND SOILS

There are five areas of swamp and bottomland in the county, the soil types being classified in the Wabash and Lamoure series and there is an area of undifferentiated peat and muck. The total area of the county covered by these soils amounts to 6.3 percent.

WABASH LOAM (49)

The Wabash loam is the largest bottomland soil and it is the fifth most extensive individual soil type in the county. It occurs along practically all of the streams of the county and it is found along many of the tributaries. Most of the areas are very narrow strips adjacent to the stream channels and subject to frequent overflow. Probably the largest development of the type is found along the South Fork of the Iowa river.

The surface soil of the Wabash loam is a dark brown mellow friable loam extending to a depth of 12 to 15 inches, grading at that point into a dark brown friable silty clay loam. The soil varies considerably in texture and other characteristics, which is true of all alluvial soils. There are scattered deposits of fine sand and coarser gravelly materials in various areas, particularly along the South Fork of the Iowa river, and a small creek just south of Steamboat Rock. In these areas the soil ranges from a coarse sandy loam to almost a pure fine sand. Along the Iowa river from a point one-half mile northwest of Alden to Eagle City, the soil is only 24 to 36 inches in depth and the underlying material is solid limestone. Fragments of limestone are found in the subsoil in these areas.

Much of the type is forested with ash, cotton wood, willow, black walnut, post oak and redhaw. Most of the type is in bluegrass sod and the chief value of the soil at present is for pasture owing to the frequent overflow and the uncertainty of crop growth.

LAMOURE SILTY CLAY LOAM (111)

The Lamoure silty clay loam is of minor importance in the county, covering 1.4 percent of the total area. It is found along the smaller streams in all parts of the county except the southeast corner. The most extensive areas are developed along Honey creek, west of Hubbard and on the county line in sections 34 and 35 of Grant township.

The surface soil of this type is a black silty clay to clay loam, 10 inches in depth. The subsoil is a dark grayish-brown, plastic clay loam to silty clay loam mottled with gray and yellowish-brown. Reddish brown iron stains are common in the lower subsoil. Varying quantities of sand and gravel are found mixed with the surface soil but there is never any large amount of these materials. The subsoil is highly calcareous and in many places the surface soil will effervesce with acid. Within the type there are included small areas of Wabash silt loam and Lamoure loam which are too small to be separated on the map. In many places there is considerable wash from the adjacent uplands and terraces and the soil has been modified somewhat by the soil washed on it. The type is level in topography, very poorly drained and is subject to overflow.

Only small acreages are at present in cultivation and on these areas corn is grown. Some hay is cut but most of the type is utilized for pasture. It needs drainage first of all, if it is to be made most productive and it would then respond to small applications of farm manure and possibly the use of a phosphate fertilizer.

WABASH SILT LOAM (26)

The Wabash silt loam is a minor type in the county, covering 0.8 percent of the total area. It occurs in narrow strips along the smaller streams in the southeastern part of the county. The chief development is along Honey creek. Some areas occur south along the Iowa river and its larger tributaries. In these latter locations, it occurs in narrow bands to the extreme outer edge of the flood plain where it joins the uplands. In these localities it is modified considerably by wash from the uplands.

The surface soil of the Wabash silt loam consists of 12 to 16 inches of a very dark brown to black heavy friable silt loam. The subsoil is a heavy compact yellowish-brown or dark brown silty clay loam. The black color of the surface soil in some places extends to a depth of 20 to 40 inches. In some areas the surface soil is heavier in texture, approaching a light silty clay loam. The lower subsoil is usually heavier, mottled with light yellowish-brown. In topography the soil is flat with a gentle slope toward the stream channel. The drainage is adequate but the soil is subject to regular overflow.

Very little of the type is forested. That along the larger streams is largely cultivated while the areas along the smaller streams are utilized for pasture. Corn is the chief crop grown with some oats and hay. Corn yields 25 to 60 bushels per acre and hay from 1 to 2 tons. This soil when cultivated would respond to applications of farm manure and lime. It would also probably be benefited by an application of a phosphate fertilizer.

WABASH SILTY CLAY LOAM (48)

The Wabash silty clay loam is a minor type in the county, covering 0.4 percent of the total area. It is developed along all of the larger streams, usually in narrow areas lying somewhat lower than the rest of the bottoms, and usually at the foot of the adjacent upland or terrace. The only extensive development is northeast of Lawn Hill along the South Fork of the Iowa river, where an area nearly three miles long, containing about 400 acres, is mapped.

The surface soil of the Wabash silty clay loam is a dark brown to black heavy sticky silty clay loam extending to a depth of 18 inches. The subsoil is a dark brown tenacious silty clay mottled with dark brown or gray. In many areas the dark brown or black color of the surface soil extends thru the three foot section. There is usually a gradual change from the surface to the subsoil. More or less coarse sand and gravel are mixed with the soil and small areas of gravel or sandy clay have been deposited over the surface.

In topography the soil is flat to depressed and the soil is naturally poorly drained. When artificial drainage is not provided water often stands on the soil for considerable periods. Small patches of muck are found in some of these areas.

The type is mainly in pasture. Some small areas have been reclaimed and planted to crops, of which corn is the chief crop. Timothy makes a good growth and native grasses are often cut for hay, yielding 1 to 2 tons per acre. To be used for cultivated crops, this soil should be thoroly drained first of all, small amounts of farm manure should be applied, it should be limed and phosphorus fertilizers might be of value.

PEAT AND MUCK (21)

There is a small area of peat and muck in the county, covering 0.4 percent of the total area. There are numerous small areas of this material scattered thru the county, the largest areas being found southwest of Alden, northeast of Iowa Falls, and four miles south of Hubbard. Many of the smaller areas could not be shown on the map because of their small extent. The areas range in size from 1 to 150 acres. They are found in former shallow undrained basins, ponds or lakes in which rushes, sedges and various water plants have grown and decayed and their remains accumulated.

Peat is composed of rough fibrous vegetable matter, dark brown in color and varying in depth from 6 inches to 4 feet. The surface has a light brown and reddish-brown fluffy appearance when dry. The subsoil is a sticky, impervious, drab or grayish-brown silty clay to clay, with gray and faint yellowish-brown mottlings and usually highly calcareous.

Muck represents a later stage in the decomposition of peat. More decomposition has occurred, more mineral soil material has been washed in from the surrounding land, the plant structure has disappeared and a very finely divided black organic material remains. Most of the areas in the county consist of peat. The areas of muck were too small to separate on the map.

The areas are usually characterized by the occurrence of muck at the edges while toward the center the peat becomes coarser, less decomposed and deeper. Ordinarily the deposits do not exceed 25 to 30 inches in depth. More than 60 percent of the peat and practically all of the muck has been drained and brought under cultivation or seeded to grass.

The uncultivated areas are in native grasses and used for pasture. Corn is the principal crop grown on the well drained or decomposed peat areas, yielding from 20 to 50 bushels per acre. Corn will not do well on newly drained peat. Small grains are inclined to lodge. Potatoes will grow successfully and other

crops such as tomatoes, onions, cabbage and sugar beets sometimes prove very profitable, depending upon market conditions.

To reclaim peat and muck areas the first treatment needed is thoro drainage. Deep plowing is of value and fall plowing aids in the decomposition of the peat. Seeding to timothy and alsike clover and then pasturing the land heavily is a desirable practice. Truck crops may often be successfully grown on these drained peat lands. Corn and small grains should not be grown until the peat has become rather completely decomposed.

Associated with peat and muck areas there also occur occasionally in some of the Webster soils, areas of so-called "alkali" spots. These spots are characterized by the appearance of a white powder on the surface in periods of dry weather. General farm crops are injured by this alkali occurrence and corn often shows a very definite injury.

The treatment recommended for reclaiming alkali soils is first of all to insure adequate drainage. This may be accomplished by running lines of tile not only thru the center of the area of peat but also thru the land immediately adjacent to the peat deposit. The alkali usually occurs in a narrow strip or areas on the edge of newly drained peat land. If the line of tile is laid around the peat as well as thru the center there is the least danger of the occurrence of an alkali spot. Liberal applications of horse manure should then be made to the spots. If manure is not available a green crop should be turned under. With these treatments the alkali spots may be very quickly reclaimed and the soil made quite as productive as in the adjacent area.

APPENDIX

THE SOIL SURVEY OF IOWA

What soils need to make them highly productive and to keep them so, and how their needs may be supplied, are problems which are met constantly on the farm today.

To enable every farmer to solve these problems for his local conditions, a complete survey and study of the soils of the state has been undertaken, the results of which will be published in a series of county reports. This work includes a detailed survey of the soils of each county, following which all the soil types, streams, roads, railroads, etc., are accurately located on a soil map. This portion of the work is being carried on in cooperation with the Bureau of Soils of the United States Department of Agriculture.

Samples of soils are taken and examined mechanically and chemically to determine their character and composition and to learn their needs. Pot experiments with these samples are conducted in the greenhouse to ascertain the value of the use of manure, fertilizers, lime and other materials on the various soils. These pot tests are followed in many cases by field experiments to check the results secured in the greenhouse. The meagerness of the funds available for such work has limited the extent of these field studies and tests have not been possible in each county surveyed. Fairly complete results have been secured, however, on the main types in the large soil areas.

Following the survey, systems of soil management which should be adopted in the various counties and on the different soils are worked out, old methods of treatment

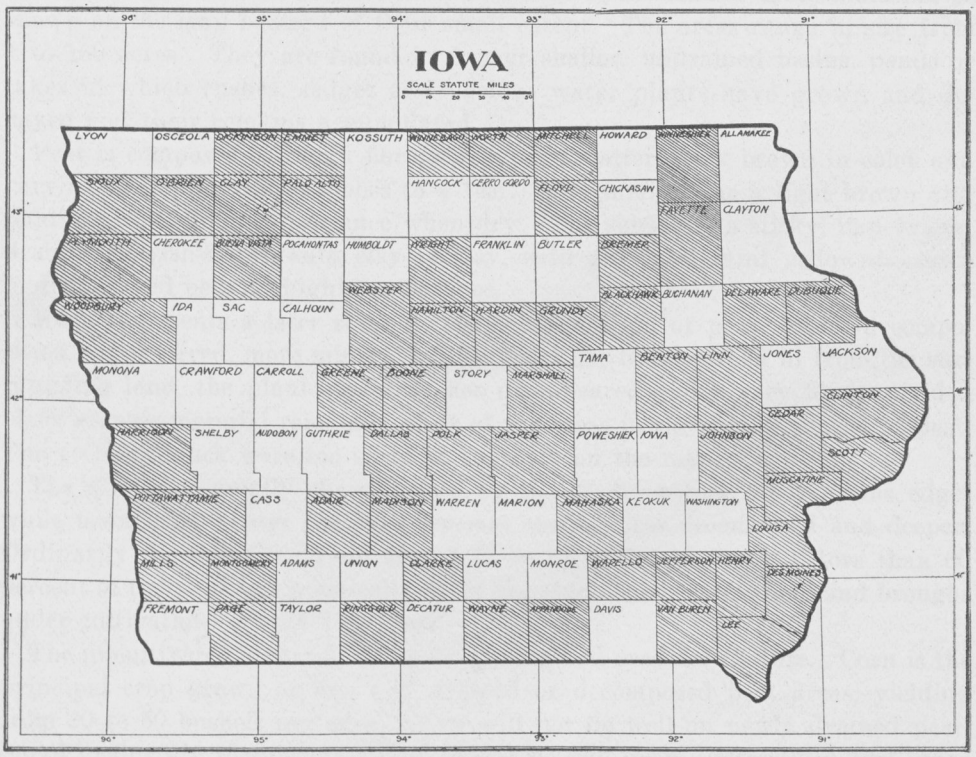

Fig. 15. Map of Iowa showing the counties surveyed.

are emphasized as necessary or their discontinuance advised, and new methods of proven value are suggested. The published reports as a whole will outline the methods which the farmers of the state must employ if they wish to maintain the fertility of their soils and to insure the best crop production.

The various counties of the state will be surveyed as rapidly as funds will permit, the number included each year being determined entirely by the size of the appropriation available for the work. The order in which individual counties will be chosen depends very largely upon the interest and demand in the county for the work. Petitions signed by the residents, and especially by the farmers or farmers' organizations of the county should be submitted to indicate the sentiment favorable to the undertaking. Such petitions are filed in the order of their receipt and aid materially in the annual selection of counties.

The reports giving complete results of the surveys and soil studies in the various counties will be published in a special series of bulletins as rapidly as the work is completed. Some general information regarding the principles of permanent soil fertility and the character, needs and treatment of Iowa soils, gathered from various published and unpublished data accumulated in less specific experimental work will be included in or appended to all the reports.

PLANT FOOD IN SOILS

Fifteen different chemical elements are essential for plant food, but many of these occur so extensively in soils and are used in such small quantities that there is practically no danger of their ever running out. Such, for example, is the case with iron and aluminum, past experience showing that the amount of these elements in the soil remains practically constant.

Furthermore, there can never be a shortage in the elements which come primarily from the air, such as carbon and oxygen, for the supply of these in the atmosphere is practically inexhaustible. The same is true of nitrogen, which is now known to be taken directly from the atmosphere by well-inoculated legumes and by certain microscopic organisms. Hence, altho many crops are unable to secure nitrogen from the air and are forced to draw on the soil supply, it is possible by the proper and frequent growing of well-inoculated legumes and their use as green manures, to store up sufficient of this element to supply all the needs of succeeding non-legumes.

Knowledge of the nitrogen content of soils is important in showing whether sufficient green manure or barnyard manure has been applied to the soil. Commercial nitrogenous fertilizers are now known to be unnecessary where the soil is not abnormal, and green manures may be used in practically all cases. Where a crop must be "forced," as in market gardening, some nitrogenous fertilizers may be of value.

THE "SOIL DERIVED" ELEMENTS

Phosphorus, potassium, calcium and sulfur, known as "soil derived" elements, may frequently be lacking in soils, and then a fertilizing material carrying the necessary element must be used. Phosphorus is the element most likely to be deficient in all soils. This is especially true of Iowa soils. Potassium frequently is lacking in peats and swampy soils, but normal soils in Iowa and elsewhere are usually well supplied with this element. Calcium may be low in soils which have borne a heavy growth of a legume, especially alfalfa; but a shortage of this element is very unlikely. It seems possible from recent tests that sulfur may be lacking in many soils, for applications of sulfur fertilizers have proved of value in some cases. However, little is known as yet regarding the relation of this element to soil fertility. If later studies show its importance for plant growth and its deficiency in soils, sulfur fertilizers may come to be considered of much value.

If the amounts of any of these soil-derived elements in soils are very low, they need to be supplied thru fertilizers. If considerable amounts are present, fertilizers containing them are unnecessary. In such cases if the mechanical and humus conditions in the soil are at the best, crops will be able to secure sufficient food from the store in the soil. For example, if potassium is abundant, there is no need of applying a potassium fertilizer; if phosphorus is deficient, a phosphate should be applied. If calcium is low in the soil, it is evident that the soil is acid and lime should be applied, not only to remedy the scarcity of calcium, but also to remedy the injurious acid conditions.

AVAILABLE AND UNAVAILABLE PLANT FOOD

Frequently a soil analysis shows the presence of such abundance of the essential plant foods that the conclusion might be drawn that crops should be properly supplied for an indefinite period. However, applications of a fertilizer containing one of the

TABLE I. PLANT FOOD IN CROPS AND VALUE

Calculating Nitrogen (N) at 16c (Sodium Nitrate ($NaNO^3$)), Phosphorus (P) at 12c (Acid Phosphate), and Potassium (K) at 6c (Potassium Chloride (KCl))

Crop	Yield	Plant food, lbs.			Value of plant food			Total value of plant food
		Nitrogen	Phosphorus	Potassium	Nitrogen	Phosphorus	Potassium	
Corn, grain.....	75 bu.	75	12.75	14	$12.00	$1.52	$0.84	$14.37
Corn, stover	2.25 T.	36	4.5	39	5.76	0.54	2.34	8.64
Corn, crop	.....	111	17.25	53	17.76	2.07	3.18	23.01
Wheat, grain ...	30 bu.	42.6	7.2	7.8	6.81	0.86	0.46	8.13
Wheat, straw ...	1.5 T.	15	2.4	27	2.40	0.28	1.62	4.30
Wheat, crop	.....	57.6	9.6	34.8	9.21	1.14	2.08	12.43
Oats, grain	50 bu.	33	5.5	8	5.28	0.66	0.48	6.42
Barley, straw ...	1.25 T.	15.5	2.5	26	2.48	0.30	1.56	8.28
Oats, crop	.....	48.5	8	34	7.76	0.96	2.04	14.70
Barley, grain ...	30 bu.	23	5	5.5	3.68	0.60	0.33	4.61
Barley, straw ...	0.75 T.	9.5	1	13	1.52	0.12	0.78	2.42
Barley, crop	.....	32.5	6	18.5	5.20	0.72	1.11	7.03
Rye, grain.....	30 bu.	29.4	6	7.8	4.70	0.72	0.46	5.88
Rye, straw	1.5 T.	12	3	21	1.92	0.36	1.26	3.54
Rye, crop	.....	41.4	9	28.8	6.62	1.08	1.72	9.42
Potatoes	300 bu.	63	12.7	90	10.08	1.25	5.40	17.00
Alfalfa, hay	6 T.	300	27	144	48.00	3.24	8.64	59.88
Timothy, hay ...	3 T.	72	9	67.5	11.52	1.08	3.95	16.55
Clover, hay.....	3 T.	120	15	90	19.20	1.80	5.40	16.40

elements present in such large quantities in the soil may bring about an appreciable and even profitable increase in crops.

The explanation of this peculiar state of affairs lies in the fact that all the plant food shown by analysis to be present in soils is not in a usable form; it is said to be *unavailable*. Plants cannot take up food unless it is in solution; hence *available* plant food is that which is in solution. Analyses show not only this soluble or available portion, but also the very much larger insoluble or unavailable part. The total amount of plant food in the soil may, therefore, be abundant for numerous crops, but if it is not made available enough, plant will suffer for proper food.

Bacteria and molds are the agents which bring about the change of insoluble, unavailable material into available form. If conditions in the soil are satisfactory for their vigorous growth and sufficient total plant food is present, these organisms will bring about the production of enough soluble material to support good crop growth. The soil conditions necessary for the best growth and action of bacteria and molds are the same as those which are required by plants. The methods necessary to maintain permanent soil fertility will, therefore, insure satisfactory action of these organisms and the sufficient production of available plant food. The nitrogen left in the soil in plant and animal remains is entirely useless to plants and must be changed to be available. Bacteria bring about this change and they are all active in normal soils which are being properly handled.

Phosphorus is found in soil mainly in the mineral known as apatite and in other insoluble substances. Potassium occurs chiefly in the insoluble feldspars. Therefore, both of these elements, as they normally occur in soils, are unavailable. However, the growth of bacteria and molds in the soil brings about a production of carbon dioxide and organic acids which act on the insoluble phosphates and potassium compounds and make them available for plant food.

Calcium occurs in the soil mainly in an unavailable form, but the compounds containing it are attacked by the soil water carrying the carbon dioxide produced by bacteria and molds and as a result a soluble compound is formed. The losses of lime from soils are largely the result of the leaching of this soluble compound.

Sulfur, like nitrogen, is present in the soils chiefly in plant and animal remains, in which form it is useless to plants. As these materials decompose, however, so-called sulfur bacteria appear and bring about the formation of soluble and available sulfates.

The importance of bacterial action in making the store of plant food in the soil available is apparent. With proper physical and chemical soil conditions, all the necessary groups of bacteria mentioned become active and a vigorous production of soluble nitrogen, phosphorus, potassium, calcium and sulfur results. If crops are

to be properly nourished, care should always be taken that the soil is in the best condition for the growth of bacteria.

REMOVAL OF PLANT FOOD BY CROPS

The decrease of plant food in the soil is the direct result of removal by crops, altho there is often some loss by leaching also. A study of the amounts of nitrogen, phosphorus, and potassium removed by some of the common farm crops will show how rapidly these elemments are used up under average farming conditions.

The amounts of these elements in various farm crops are given in table I. The amount of calcium and sulfur in the crops is not included, as it is only recently that the removal of these elements has been considered important enough to warrant analyses.

The figures in the table show also the value of the three elements contained in the different crops, calculated from the market value of fertilizers containing them. Thus the value of nitrogen is figured at 16 cents per pound, the cost of the elements in nitrate of soda; phosphorus at 12 cents, the cost in acid phosphate, and potassium at 6 cents, the cost in muriate of potash.

It is evident from the table that the continuous growth of any common farm crop without returning these three important elements will lead finally to a shortage of plant food in the soil. The nitrogen supply is drawn on the most heavily by all the crops, but in the case of alfalfa and clover only a small part should be taken from the soil. If these legumes are inoculated as they should be, they will take most of their nitrogen from the atmosphere. The figures are therefore entirely too high for the nitrogen taken from the soil by these two crops, but the loss of nitrogen from the soil by removal in non-leguminous crops is considerable. The phosphorus and potassium in the soil are also rapidly reduced by the growth of ordinary crops. While the nitrogen supply may be kept up by the use of leguminous green manure crops, phosphorus and potassium must be supplied by the use of expensive commercial fertilizers.

The cash value of the plant food removed from soils by the growth and sale of various crops is considerable. Even where the grain alone is sold and the crop residues are returned to the soil, there is a large loss of fertility, and if the entire crop is removed and no return made, the loss is almost doubled. It is evident, therefore, that in calculating the actual income from the sale of farm crops, the value of the plant food removed from the soil should be subtracted from the proceeds at least in the case of constituents which must be replaced at the present time.

Of course, if the crops procured are fed on the farm and the manure carefully preserved and used, a large part of the valuable matter in the crops will be returned to the soil. This is the case in livestock and dairy farming where the products sold contain only a portion of the valuable elements of plant food removed from the soil. In grain farming, however, green manure crops and commercial fertilizers must be depended upon to supply plant food deficiencies in the soil. It should be mentioned that the proper use of crop residues in this latter system of farming reduces considerably plant food loss.

REMOVAL FROM IOWA SOILS

It has been conservatively estimated that the plant food taken from Iowa soils and shipped out of the state in grain amounts to about $30,000,000 annually. This calculation is based on the estimate of the secretary of the Western Grain Dealers' Association that 20 percent of the corn and 35 to 40 percent of the oats produced in the state is shipped off the farms.

This loss of fertility is unevenly distributed over the state, varying as farmers do more or less livestock and dairy farming or grain farming. In grain farming, where no manure is produced and the entire grain crop is sold, the soil may very quickly become deficient in certain necessary plant foods. Eventually, however, all soils are depleted in essential food materials, whatever system of farming is followed.

This loss of fertility is great enough to demand serious attention. Careful consideration should certainly be given to all means of maintaining the soils of the state in a permanently fertile condition.

PERMANENT FERTILITY IN IOWA SOILS

The preliminary study of Iowa soils, already reported, revealed the fact that there is not an inexhaustible supply of nitrogen, phosphorus and potassium in the soils of the state. Potassium was found in much larger amounts than the other two elements, and it was concluded, therefore, that attention should be centered at the present time on nitrogen and phosphorus. In spite of the fact that Iowa soils are still comparatively fertile and crops are still large there is abundant evidence at hand to prove that the best possible yields of certain crops are not being obtained in many cases because of the lack of necessary plant foods or because of the lack of proper conditions in

the soil for the growth of plants and the production, by bacteria, of available plant food.

Proper systems of farming will insure the production of satisfactory crops and the maintenance of permanent fertility and the adoption of such systems should not be delayed until the crop yields are much lower, for then it will involve a long, tedious and very expensive fight to bring the soil back to a fertile condition. If proper methods are put into operation while comparatively large amounts of certain plant foods are still present in the soil, it is relatively easy to keep them abundant and attention may be centered on other elements likely to be limiting factors in crop production.

Soils may be kept permanently fertile by adopting certain practices which will be summarized here.

CULTIVATION AND DRAINAGE

Cultivation and drainage are two of the most important farm operations in keeping the soil in a favorable condition for soil production, largely because they help control the moisture in the soil.

The moisture in soils is one of the most important factors governing crop production. If the soil is too dry, plants suffer for lack of water necessary to bring them their food and also for lack of available plant food. Bacterial activities are so restricted in dry soils that the production of available plant food practically ceases. If too much moisture is present, plants likewise refuse to grow properly because of the exclusion of air from the soil and the absence of available food. Decay is checked in the absence of air, all beneficial bacterial action is limited and humus, or organic matter, containing plant food constituents in an unavailable form, accumulates. The infertility of low-lying, swampy soils is a good illustration of the action of excessive moisture in restricting plant growth by stopping aeration and limiting beneficial decay processes.

While the amount of moisture in the soil depends very largely on the rainfall, any excess of water may be removed from the soil by drainage and the amount of water present in the soil may be conserved during the periods of drouth by thoro cultivation or the maintaining of a good mulch. The need for drainage is determined partly by the nature of the soil, but more particularly by the subsoil. If the subsoil is a heavy, tight clay, a surface clay loam will be rather readily affected by excessive rainfall. On the other hand, if the surface soil is sandy, a heavy subsoil will be of advantage in preventing the rapid drying out of the soil and also in checking losses of valuable matter by leaching.

Many acres of land in the Wisconsin drift area in Iowa have been reclaimed and made fertile thru proper drainage, and one of the most important farming operations is the laying of drains to insure the removal of excessive moisture in heavy soils.

The loss of moisture by evaporation from soils during periods of heavy drouth may be checked to a considerable extent if the soil is cultivated and a good mulch is maintained. Many pounds of valuable water are thus held in the soil and a satisfactory crop growth secured when otherwise a failure would occur. Other methods of soil treatment, such as liming, green manuring and the application of farm manures, are also important in increasing the water-holding power of light soils.

THE ROTATION OF CROPS

Experience has shown many times that the continuous growth of one crop takes the fertility out of a soil much more rapidly than a rotation of crops. One of the most important farm practices, therefore, from the standpoint of soil fertility, is the rotation of crops on a basis suited to the soil, climatic, farm and market conditions. The choice of crops is so large that no difficulty should be experienced in selecting those suitable for all conditions.

Probably the chief reason why the rotation of crops is beneficial may be found in the fact that different crops require different amounts of the various plant foods in the soil. One particular crop will remove a large amount of one element and the next crop if it be the same kind, will suffer for a lack of that element. If some other crop, which does not draw as heavily on that particular plant food, is rotated with the former crop, a balance in available plant food is reached.

Where a cultivated crop is grown continuously, there is a much greater loss of organic matter or humus in the soil than under a rotation. This fact suggests a second explanation for the beneficial effects of crop rotation. With cultivation, bacterial action is much increased and the humus in the soil may be decomposed too rapidly and the soil injured by the removal of the valuable material. Then the production of available plant food in the soil will be hindered or stopped and crops may suffer. The use of legumes in rotations is of particular value since when they are well inoculated and turned under, they not only supply organic matter to the soil, but they also increase the nitrogen content.

There is a third explanation of the value of rotations. It is claimed that crops in their growth produce certain substances called "toxic" which are injurious to the

same crop, but have no effect on certain other crops. In a proper rotation the time between two different crops of the same plant is long enough to allow the "toxic" substance to be disposed of in the soil or made harmless. This theory has not been commonly accepted, chiefly because of the lack of confirmatory evidence. It seems extremely doubtful if the amounts of these "toxic" substances could be large enough to bring about the effects evidenced in continuous cropping.

But, whatever the reason for the bad effects of continuous cropping, it is evident that for all good systems of farming some definite rotation should be adopted, and that rotations should always contain a legume, because of the value of such crops to the soil. In no other way can the humus and nitrogen content of soils be kept up so cheaply and satisfactorily as by the use of legumes, either as regular or "catch" crops in the rotation.

MANURING

There must always be enough humus, or organic matter, and nitrogen in the soil if satisfactory crops are to be secured. Humus not only keeps the soil in the best physical condition for crop growth, but it supplies a considerable portion of nitrogen. An abundance of humus may always be considered a reliable indication of the presence of much nitrogen. This nitrogen does not occur in a form available for plants, but with proper physical conditions in the soil, the nonusable nitrogen in the animal and vegetable matter which makes up the humus, is made usable by numerous bacteria and changed into soluble and available nitrates.

The humus, or organic matter, also encourages the activities of many other bacteria which produce carbon dioxide and various acids which dissolve and make available the insoluble phosphorus and potassium in the soil.

Three materials may be used to supply the organic matter and nitrogen of soils. These are farm manure, crop residues and green manure, the first two being much more common.

Farm manure is composed of the solid and liquid excreta of animals, litter, unconsumed foods and other waste materials, and supplies an abundance of organic matter, much nitrogen and millions of valuable bacteria. It contains, in short, a portion of the plant food present in the crops originally removed from the soil and in addition the bacteria necessary to prepare this food for plant use. If it were possible to apply enough amounts of farm manure, no other material would be necessary to keep the soil in the best physical condition, insure efficient bacterial action and keep up the plant food supply. But manure cannot serve the soil thus efficiently, for even under the very best methods of treatment and storage, 15 per cent of its valuable constituents, mainly nitrogen, are lost. Furthermore, only in a very few instances is enough produced on a farm to supply its needs. On practically all soils, therefore, some other material must be applied with the manure to maintain fertility.

Crop residues, consisting of straw, stover, roots and stubble, are important in keeping up the humus, or organic matter contents of soils. Table I shows that a considerable portion of the plant food removed by crops is contained in the straw and stover. On all farms, therefore, and especially on grain farms, the crop residues should be returned to the soil to reduce the losses of plant food and also to aid in maintaining the humus content. These materials alone are, of course, insufficient and farm manure must be used when possible, and green manures also.

Green manuring should be followed to supplement the use of farm manures and crop residues. In grain farming, where little or no manure is produced, the turning under the leguminous crops for green manures must be relied upon as the best means of adding humus and nitrogen to the soil, but in all other systems of farming also it has an important place. A large number of legumes will serve as green manure crops and it is possible to introduce some such crop into almost any rotation without interfering with the regular crop. It is this peculiarity of legumes, together with their ability to use the nitrogen of the atmosphere when well inoculated and thus increase the nitrogen content of the soil which gives them their great value as green manure crops.

It is essential that the legumes used be well inoculated. Their ability to use the atmospheric nitrogen depends on that. Inoculation may be accomplished by the use of soil from a field where the legume has previously been successfully grown and well inoculated or by the use of inoculating materials that may be purchased. If the legume has never been grown on the soil before, or has been grown without inoculation, then inoculation should be practiced by one of these methods.

By using all the crop residues, all the manure produced on the farm, and giving well-inoculated legumes a place in the rotation for green manure crops, no artificial means of maintaining the humus and nitrogen content of soils need be resorted to.

THE USE OF PHOSPHORUS

Iowa soils are not abundantly supplied with phosphorus. Moreover, it is possible by the use of manures, green manures, crop residues, straw, stover, etc., to return to the soil the entire amount of that element removed by crops. Crop residues, stover and

straw merely return a portion of the phosphorus removed, and while their use is important in checking the loss of the element, they cannot stop it. Green manuring adds no phosphorus that was not used in the growth of the green manure crop. Farm manure returns part of the phosphorus removed by crops which are fed on the farm, but not all of it. While, therefore, immediate scarcity of phosphorus in Iowa soils cannot be positively shown, analyses and results of experiments show that in the more or less distant future, phosphorus must be applied or crops will suffer for a lack of this element. Furthermore, there are indications that its use at present would prove profitable in some instances.

Phosphorus may be applied to soils in three commercial forms, bone meal, acid phosphate and rock phosphate. Bone meal cannot be used generally, because of its extremely limited production, so the choice rests between rock phosphate and acid phosphate. Experiments are now under way to show which is more economical for farmers in the state. Many tests must be conducted on a large variety of soil types, under widely differing conditions, and thru a rather long period of years. It is at present impossible to make these experiments as complete as desirable, owing to small appropriations for such work, but the results secured from the tests now in progress will be published from time to time in the different county reports.

Until such definite advice can be given for individual soil types, it is urged that farmers who are interested make comparisons of rock phosphate and acid phosphate on their own farms. In this way they can determine at first hand the relative value of the two materials. Information and suggestions regarding the carrying out of such tests may be secured upon application to the Soils Section.

LIMING

Practically all crops grow better on a soil which contains lime, or in other words, on one which is not acid. As soils become acid, crops grow smaller, bacterial activities are reduced and the soil becomes infertile. Crops are differently affected by acidity in the soil; some refuse to grow at all; others grow but poorly. Only in a very few instances can a satisfactory crop be secured in the absence of lime. Therefore, the addition of lime to soils in which it is lacking is an important principle in permanent soil fertility. All soils gradually become acid because of the losses of lime and other basic materials thru leaching the production of acids in the decomposition processes constantly occurring in soils. Iowa soils are no exceptions to the general rule, as was shown by the tests of many representative soils reported in Bulletin No. 151 of this station. Particularly are the soils in the Iowan drift, Mississippi loess and Southern Iowa loess areas likely to be acid.

All Iowa soils should therefore be tested for acidity before the crop is seeded, particularly when legumes, such as alfalfa or red clover, are to be grown. Any farmer may test his own soil and determine its need of lime, according to simple directions in bulletin No. 151, referred to above.

As to the amount of lime needed for acid soils as a general rule sufficient should be applied to neutralize the acidity in the surface soil and then an additional amount of one or two tons per acre.

SOIL AREAS IN IOWA

There are five large soil divisions in Iowa, the Wisconsin drift, the Iowan drift, the Missouri loess, the Mississippi loess and the Southern Iowa loess. These five divisions of the soils of the state are based on the geological forces which brought about the formation of the various soil areas. The various areas are shown in the map, fig. 15.

With the exception of the northeastern part of the state, the whole surface of Iowa was in ages past overrun by the great continental ice sheets. These great masses of ice moved slowly over the land, crashing and grinding the rocks beneath and carrying along with them the material which they accumulated in their progress. Five ice sheets invaded Iowa at different geological eras, coming from different directions and carrying therefore, different rock material with them.

The deposit, or sheet, of earth debris left after the ice of such glaciers melts is called "glacial till" or "drift" and is easily distinguished by the fact that it is usually a rather stiff clay containing pebbles of all sorts as well as large boulders of "nigger heads." Two of these drift areas occur in Iowa today, the Wisconsin drift and the Iowan drift, covering the north central part of the state. The soils of these two drift areas are quite different in chemical composition, due primarily to the different ages of the two ice invasions. The Iowan drift was laid down at a much earlier period and is somewhat poorer in plant food than the Wisconsin drift soil, having undergone considerable leaching in the time which has elapsed since its formation.

The drift deposits in the remainder of the state have been covered by so-called loess soils, vast accumulations of dust-like materials which settled out of the air during a period of geological time when climatic conditions were very different than at present. These loess soils are very porous in spite of their fine texture and they rarely contain

large pebbles or stones. They present a strong contrast to the drift soils, which are somewhat heavy in texture and filled with pebbles and stone. The three loess areas in the state, the Missouri, the Mississippi and the Southern Iowa, are distinguished by differences in texture and appearance, and they vary considerably in value for farming purposes. In some sections the loess is very deep, while in other places the underlying leached till or drift soil is very close to the surface. The fertility of these soils and their needs are greatly influenced, therefore, by their depth.

It will be seen that the soils of the state may be roughly divided into two classes, drift soils and loess soils, and that further divisions may then be made into various drift and loess soils because of differences in period of formation, characteristics and general composition. More accurate information demands, however, that further divisions be made. The different drift and loess soils contain large numbers of soil types which vary among themselves, and each of these should receive special attention.

THE SOIL SURVEY BY COUNTIES

It is apparent that a general survey of the soils of the state can give only a very general idea of soil conditions. Soils vary so widely in character and composition, depending on many other factors than their source, that definite knowledge concerning their needs can be secured only by thoro and complete study of them in place in small areas. Climatic conditions, topography, depth and character of soil, chemical and mechanical composition and all other factors affecting crop production must be considered.

This is what is accomplished by the soil survey of the state by counties, and hence the needs of individual soils and proper systems of management may be worked out in much greater detail and be much more complete than would be possible by merely considering the large areas separated on the basis of their geological origin. In other words, while the unit in the general survey is the geological history of the soil area, in the soil survey by counties or any other small area, the unit is the soil type.

GENERAL SOIL CHARACTERISTICS

Soil types possess more or less definite characteristics which may be determined largely in the field, altho some laboratory study is necessary for final disposition. Usually the line of separation between adjoining soil types is quite distinct and it is a simple matter to locate the type boundaries. In some cases, however, there is a gradation from one type to another and then the boundaries may be fixed only with great difficulty. The error introduced into soil survey work from this source is very small and need cause little concern.

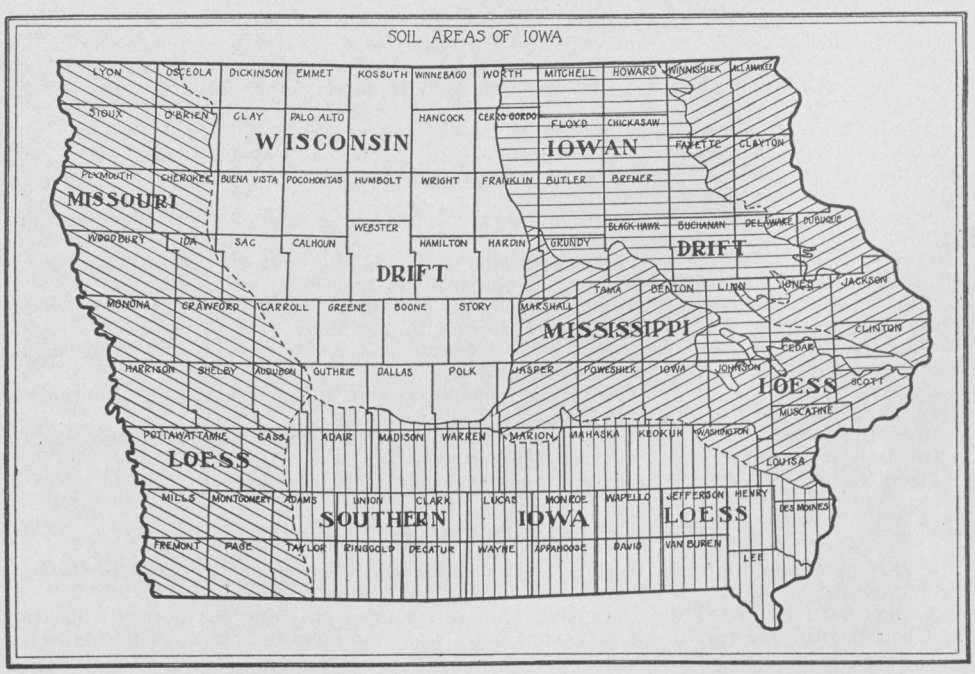

Fig. 16. Map showing the principal soil areas in Iowa.

The factors which must be taken into account in establishing soil types have been well enumerated by the Illinois Experiment Station in its Soil Report No. 1. They are:

1. The geological origin of the soil, whether residual, glacial, loessial, alluvial, colluvial or cumulose.
2. The topography or lay of the land.
3. The structure or depth and character of the surface, subsurface and subsoil.
4. The physical and mechanical composition of different strata composing the soil, as the percentages of gravel, sand, silt, clay and organic matter which they contain.
5. The texture or porosity, granulation, friability, plasticity, etc.
6. The color of the strata.
7. The natural drainage.
8. The agricultural value based upon its natural productiveness.
9. Native vegetation.
10. The ultimate chemical composition and reaction.

The common soil constituents may be given as follows:†

Organic matter	All partially destroyed or decomposed vegetable and animal material.
Inorganic matter	Stones—over 32 mm.* Gravel—32—2.0 mm. Very coarse sand—2.0—1.0 mm. Coarse sand—1.0—0.5 mm. Medium sand—0.5—0.25 mm. Fine sand—0.25—0.10 mm. Very fine sand—0.10—0.05 mm. Silt—0.05—0.00 mm.

SOILS GROUPED BY TYPES

The general groups of soils by types are indicated thus by the Bureau of Soils.

Peats—Consisting of 35 percent or more of organic matter, sometimes mixed with more or less sand or soil.

Peaty Loams—15 to 35 percent organic matter mixed with much sand and silt and a little clay.

Mucks—25 to 35 percent of partly decomposed organic matter mixed with much clay and some silt.

Clays—Soils with more than 30 percent clay, usually mixed with much silt; always more than 50 percent silt and clay.

Silty Clay Loams—20 to 30 percent clay and more than 50 percent silt.

Clay Loams—20 to 30 percent clay and less than 50 percent silt and some sand.

Silt Loams—20 percent clay and more than 50 percent silt mixed with some sand.

Loams—Less than 20 percent clay and less than 50 percent silt and from 30 to 50 percent sand.

Sandy Clays—20 percent silt and small amounts of clay up to 30 percent.

Fine Sandy Loams—More than 50 percent fine sand and very fine sand mixed with less than 25 percent very coarse sand, coarse sand and medium sand, much silt and a little clay; silt and clay 20 to 50 percent.

Sandy Loams—More than 25 percent very coarse, coarse and medium sand; silt and clay 20 to 50 percent.

Very Fine Sand—More than 50 percent fine sand and less than 25 percent very coarse, coarse and medium sand, less than 20 percent silt and clay.

Fine Sand—More than 50 percent fine sand and less than 25 percent very coarse, coarse and medium sand, less than 20 percent silt and clay.

Sand—More than 25 percent very coarse, coarse and medium sand, less than 50 percent fine sand, less than 20 percent silt and clay.

Coarse Sand—More than 25 percent very coarse, coarse and medium sand, less than 50 percent of other grades, less than 20 percent silt and clay.

Gravelly Loams—25 to 50 percent very coarse sand and much sand and some silt.

Gravels—More than 50 percent very coarse sand.

Stony Loams—A large number of stones over one inch in diameter.

METHODS USED IN THE SOIL SURVEY

It may be of some interest to state briefly the methods which are followed in the field in surveying the soils.

As has been indicated the completed map is intended to show the accurate location and boundaries, not only of all soil types but also of the streams, roads, railroads, etc.

The first step, therefore, is the choice of an accurate base map and any official map of

*25 mm. equals 1 in. †Bureau of Soils Book.

the county may be chosen for this purpose. Such maps are always checked to correspond correctly with the land survey. The location of every stream, road and railroad on the map is likewise carefully verified and corrections are frequently necessary. When an accurate base map is not available the field party must first prepare one.

The section is the unit area by which each county is surveyed and mapped. The distances in the roads are determined by an odometer attached to the vehicle, and in the field by placing, which is done with accuracy. The directions of the streams, roads, railroads, etc., are determined by the use of the compass and the plane table. The character of the soil types is ascertained in the section by the use of the auger, an instrument for sampling both the surface soil and the subsoil. The boundaries of each type are then ascertained accurately in the section and indicated on the map. Many samplings are frequently necessary, and individual sections may contain several soil types and require much time for mapping. In other cases, the entire section may contain only one soil type, which fact is readily ascertained, and in that case the mapping may proceed rapidly.

When one section is completed, the party passes to the next section and the location of all soil types, streams, etc., in that section is then checked with their location in the adjoining area just mapped. Careful attention is paid to the topographic features of the area, or the "lay of the land," for the character of the soils is found to correspond very closely to the conditions under which they occur.

The field party is composed of two men, and all observations, measurements and soil type boundaries are compared and checked by each man.

The determinations of soil types are verified also by inspection and by consultation with those in charge of the work at the Bureau of Soils and at the Iowa Agricultural Experiment Station. When the entire county is completed, all the section maps of field sheets are assembled and any variations or questionable boundaries are verified by further observations of the particular area.

The completed map, therefore, shows as accurately as possible all soils and soil boundaries, and it constitutes also an exact road map of the county.